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# Price Comparison Websites

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# Price Comparison Websites

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## Abstract

The large and growing industry of price comparison websites (PCWs) or “web aggregators” is poised to benefit consumers by increasing competitive pricing pressure on firms by acquainting shoppers with more prices. However, these sites also charge firms for sales, which feeds back to raise prices. I find that introducing any number of PCWs to a market *increases* prices for all consumers, both those who use the sites, and those who do not. I then use my framework to identify ways in which a more competitive environment could be achieved. (*JEL: L11, L86, D43*)

**Keywords:** online markets; price comparison websites; price competition; price dispersion

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# 1 Introduction

Over the past two decades a new industry of price comparison websites (PCWs) or “web aggregators” has emerged. The industry has enabled consumers to check the prices of many firms selling a particular service or product simultaneously in one place. This promises to be particularly helpful to consumers in a world where prices of even seemingly homogeneous items are typically dispersed. The sites are popular in many countries, and in many markets including utilities, financial services, hotels, flights and durable goods.<sup>1</sup> These sites command billions of dollars of revenue annually.<sup>2</sup> In the UK, PCWs for utilities and financial services have been particularly successful. In 2016 the four largest aggregators turned over approximately £800m (\$1.1bn).<sup>3</sup> In 2017, it is estimated that 85% of consumers have used such a site (CMA, 2017a).

The Internet has altered search costs, allowing consumers to compare prices across firms in a matter of clicks, intensifying competitive pricing pressure between firms. While a consumer may not know of all the firms in a market, a PCW can expose the full list of market offerings, maximizing inter-firm pricing pressure. However, underlying this increased competition are the fees paid by firms who sell their products through the websites. As an example, these are understood to be approximately £60 (\$80) for a customer switching gas and electricity provider in the UK.<sup>4</sup> These fees, in turn, represent a marginal cost faced by producers, affecting their pricing decisions. The industry gleans substantial profits from these fees. As such, it is not clear whether the central premise that PCWs lower prices is valid. This tension is encapsulated in a quote from the BBC:

“There’s another cost in the bill. It’s hidden, it’s kept confidential, and yet it’s for a part of the industry that appears to be on the consumers’ side. This is the cut of the bill taken by price comparison websites, in return for referring customers. The recommendation to switch creates churn in the market, and it is seen by supplier companies as worth paying high fees to the websites. Whether or not customers choose to use the sites, the cost to the supplier is embedded within bills for all customers.”<sup>5,6</sup>

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<sup>1</sup>Examples for utilities and services include Money Supermarket and Go Compare; for flights Skyscanner and Flights.com; for hotels Expedia and Booking.com; and for durable goods Amazon Marketplace and Ebay.

<sup>2</sup>Regarding travel services, Priceline Group (Booking.com and Priceline.com) and Expedia Inc. (Expedia.com and Hotels.com) made approximately \$6bn in total agency revenues in 2014. Regarding durable goods, Amazon Marketplace sold 2 billion items from third-party sellers. See their 2014 Annual Reports for details.

<sup>3</sup>The “big four” are Money Supermarket, Compare the Market, Go Compare and Confused.com. Financial information is from annual reports where available, otherwise inferred from parent group reports. Specifically, the parent company of the UK’s largest aggregator, Compare the Market does not release disaggregated information. I conservatively assume that it has the same revenues as the second-largest, Money Supermarket.

<sup>4</sup>See BBC (2015), <http://www.bbc.com/news/business-31110625>. Fees are significant elsewhere too e.g., at least 15-25% for hotel-reservations (Daily Mail, 2015, <http://www.dailymail.co.uk/news/article-3044298/Hotel-guests-fleeced-online-agents-Hoteliers-say-forced-hike-prices-cover-25-commission-taken-websites.html>).

<sup>5</sup>BBC (2014), <http://www.bbc.com/news/uk-scotland-scotland-business-25743336>.

<sup>6</sup>US Senator Amy Klobuchar expressed a similar concern regarding hotel-reservation sites: “The whole idea of

I examine this “churn” and address the fundamental question of whether consumers are better off with a PCW in the marketplace. I characterize when all consumers, both those who do and those who do not use the sites, are made worse off following the introduction of PCWs in homogeneous-good markets.

In my model, the introduction of PCWs causes consumers to lose on average, rather than firms. This is because, in equilibrium, PCW fees are passed on by firms to consumers in higher prices. However, my main result is stronger than this. My model features two types of consumers: active consumers who use PCWs in equilibrium, and inactive consumers who buy directly from a particular firm (e.g., due to a lack of information, limited internet access, especially high search or switching costs, inertia, or brand loyalty). Although active consumers are always better off than inactive consumers in equilibrium, my main result is that *both* types are made worse off by the introduction of a monopolist PCW, or any number of competing PCWs. This is the first article in this setting to show such results, reversing those in the existing literature, which I show can be seen as special limiting cases.

My model supposes that there are  $n + k$  websites: one for each of the  $n \geq 2$  firms that produce the homogenous good, and one for each of the  $k \geq 1$  PCWs. In the setting without PCWs, firms simultaneously choose a price and active consumers search. For the setting with PCWs, I add a preliminary stage at which PCWs announce the commission that firms must pay for a sale made through the site. Each active consumer is aware of  $q > 1$  of the  $n$  firms in the market and face a small search cost for each website they visit. Without PCWs, active consumers visit the websites of the firms they know, learning  $q$  prices. After the introduction of the PCW, they visit the PCW instead, where they learn all  $n$  prices in equilibrium, and firms pay commission for sales to the PCW. I show that the equilibrium distribution of prices is pushed up by the introduction of any number of PCWs: their equilibrium choice of commission raises prices in such a way that both active and inactive consumers are worse off.

A primary novel feature of my model is that I obtain price dispersion in equilibrium with or without price comparison websites. Price dispersion is not an assumption in my model; it arises endogenously in equilibrium from the fact that some consumers have incomplete information. Normatively, in a world where consumers are only informed about a subset of prices, price dispersion implies that there is some positive probability they do not all see the lowest price. This, in turn, provides an economic rationale for a player that can reveal the complete set of market offerings, namely a price comparison website. Descriptively, the model’s prediction of price dispersion mirrors the reality that price dispersion has been a pertinent feature in markets over time, even for seemingly homogeneous products. A general sentiment in the early days of

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cheaper hotels is very good, but if it all starts to come under one company, you can easily foresee the situation where they can charge higher commissions that are then passed on to consumers.” New York Times (2015), [http://www.nytimes.com/2015/09/01/business/hotels-direct-booking-online-travel-sites.html?\\_r=0](http://www.nytimes.com/2015/09/01/business/hotels-direct-booking-online-travel-sites.html?_r=0).

the Internet was that we would see a movement towards a realization of the law of one price. It seems reasonable to speculate that price-aggregation services such as PCWs would amplify that movement by reducing informational barriers. In sharp contrast, my analysis highlights that PCWs have a strong incentive to steer the market away from the law of one price to keep demand for their services afloat.

The main result of this paper is that the equilibrium fee that PCWs charge for a sale through their sites is sufficiently high to negate the benefits from the increased inter-firm competition. The issue stems from the fact that equilibria are such that firms list their prices ubiquitously (multi-home), while consumers visit only one PCW (single-home), a pattern often observed in the relevant markets.<sup>7</sup> Regardless of the number of PCWs, this leads to a situation where each PCW is effectively a monopolist (or “bottleneck”) gatekeeper for the consumers who patronize it. The heart of the problem is reminiscent of the Diamond paradox applied not to sellers, but to aggregators. The resulting lack of downward competitive pressure on commissions allows the monopoly rate of commission to be sustained in equilibrium with any number of PCWs in the market, a rate that I show to be tempered by firms’ outside option, but high enough to increase expected prices for all consumers, relative to a world without the industry. I show this result to be broadly robust to variety of alternate assumptions and settings including price-discriminating firms, meta-sites, ad valorem fees, and the extensive search margin.

I also make novel points for policy-makers. First, my analysis shows that where the introduction of PCWs into a market is itself considered a policy, it may harm consumers. Second, through extensions of the model I identify policies and practices more- and less-suited to generate meaningful competition between PCWs. I show that enforcing fee-transparency on the part of PCWs is able to produce a competitive outcome, but that it relies on unrealistic coordination among consumers. In contrast, I show how inter-PCW competition is more naturally ignited when PCWs compete over variables on the buyer-side of the market e.g., consumer-access fees and PCW-funded discounts. As such, I show that to create an effectual competitive environment, policy should focus on providing an environment where PCWs compete for consumers *directly* (e.g., through discounts) rather than *indirectly* (e.g., through commissions).

Next I review the literature, then present the model and its equilibrium, which I then perform comparative statics upon. I then extend the analysis and evaluate ways in which to stimulate PCW competition, before making some concluding remarks. Proofs are in the Appendix.

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<sup>7</sup>The UK’s Competition & Markets Authority analyzed data provided by PCWs and firms finding consumers typically single-home (at rates of up to 89%) while firms tend to multi-home (CMA, 2017d, paragraphs 2.5, 2.55).

## 2 Literature

It is well known that some forms of intermediation can reduce welfare. For example, double marginalization emerges when an upstream firm supplies an intermediate good at a cost to a downstream firm that in turn produces the final product. There are many distinctions here, but the most fundamental is that a PCW directly affects consumers' information and hence competition. This inherent capacity of PCWs to increase competition between firms means that there is scope for such an intermediary to have beneficial effects, especially for consumers. Another stream of research ignited by Rubinstein and Wolinsky (1987) employs dynamic matching settings with buyers, sellers, and middlemen. Building on that approach, Kultti, Takalo, and Vähämaa (2019) allow buyers and sellers to become middlemen, a phenomenon they show can lower welfare by diverting resources from production and decreasing match efficiency. In contrast, I study websites whose existence per se does not affect the presence of firms or consumers, and instead focus on the informational and price effects of PCWs.

In pioneering work, Baye and Morgan (2001) investigate the strategic incentives of a PCW or “information gatekeeper”. My model builds on this conceptualization of a PCW as a provider of information but is distinct in many key respects, including those reflecting changes in technology and industry practices over the past two decades. I emphasize the most important of these developments here to provide a contrast. In the classic Baye and Morgan setup, without the PCW each consumer is served by a *single* “local” firm that sells at the monopoly price (it is too costly for consumers to travel to another store). As a result, consumers benefit from the introduction of a PCW, because firms must compete for the business of consumers who enjoy free access to the site. In the modern online marketplace however, firms also have their own websites. In the absence of an aggregator, consumers do not need to physically travel to purchase the good; they can visit another firm's website just as easily as they could an aggregator's. This suggests that without such a clearing-house, it is implausible that no consumer compares prices. This paper contributes by showing that as long as *some* consumers engage in *some* comparison in a setting without an aggregator, the introduction of one can cause prices to be higher for *all* consumers. These results obtain in the absence of intermediaries directing consumers to products (Armstrong and Zhou, 2011; De Cornière and Taylor, 2019; Teh and Wright, 2020) or sellers coordinating across platforms (Karle, Peitz, and Reisinger, 2019).

More broadly, this article contributes to the literature on “clearing-house” search models (see for example, Arnold, Li, Saliba, and Zhang, 2011; Arnold and Zhang, 2014; Baye and Morgan, 2001, 2009; Baye, Morgan, and Scholten, 2004; Chioveanu, 2008; Johnen and Ronayne, 2020; Moraga-González and Wildenbeest, 2012; Rosenthal, 1980; Salop and Stiglitz, 1977; Shilony, 1977; Varian, 1980). These models rationalize price-dispersion in homogeneous goods mar-

kets.<sup>8</sup> Indeed, price dispersion has persisted despite the advances of technology such the Internet and comparison sites. Early studies documented marked dispersion in the online markets for various goods e.g., Baye, Morgan, and Scholten (2004); Brynjolfsson and Smith (2000). A recent study by Gorodnichenko, Sheremirov, and Talavera (2018) finds substantial cross-seller variation in online prices, and voices support for clearing-house models that categorize consumers into those more- and less-informed. Congruent with their empirical work, the equilibria in my model feature price dispersion regardless of whether there is an aggregator. Without a PCW, this is because *some* price comparisons are undertaken by consumers. That there is price dispersion without an aggregator is a novel feature of my model that makes clear the economic rationale for such a platform: to provide price information in a market where prices differ.

Furthermore, producing price dispersion with a PCW that employs the pricing mechanism seen in practice, is a challenge. In the aggregator industry, fees are typically charged to firms rather than consumers, and there has been a shift away from charging one-off fixed fees toward pay-per-sale fees i.e., setting the fixed component of a two-part tariff to zero. This transition is rationalized as profit-maximizing PCW behavior by Baye, Gao, and Morgan (2011). However, absent some other exogenous fixed cost to a firm of listing on the PCW (e.g., transaction costs), price-dispersion vanishes in equilibrium. I do not deny the existence of such additional costs, but emphasize that dispersion arises in my framework without an appeal to fixed listing costs. Finally, another challenge in this literature is to model multiple clearing-houses and study competition between them. My analyses allow for any number of PCWs.

A wider relevant literature is that of two-sided markets, initiated by Rochet and Tirole (2003) (see also Armstrong, 2006; Caillaud and Jullien, 2003; Ellison and Fudenberg, 2003; Reisinger, 2014). These articles model platforms where two sides of a market e.g., buyers and sellers, meet to trade, focusing on optimal platform pricing and the effect of network externalities with differentiated products and platforms. The models do not explicitly model the seller-side competition that is central to my setting. More recent contributions do, e.g., Belleflamme and Peitz (2010); Boik and Corts (2016); Hagiu (2009); Johnson (2017), but they model the platform as the only available technology, which is not appropriate for the questions I address. Indeed, in related work, Johansen and Vergé (2016) argue that some of these models rely crucially on the implicit or explicit assumption(s) that firms do not compete against each other and/or do not choose whether to sell through the platform. Inter-firm competition is at the center of the model and I allow firms to choose whether to participate on the platform. One early message from this literature is that competing platforms can sustain monopoly fees on the multi-homing side (e.g., firms) when the other side (e.g., consumers) single-homes. My analysis reinforces this

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<sup>8</sup>Related explanations of price dispersion more focused on search costs include e.g., Stigler (1961); Burdett and Judd (1983); Stahl (1989, 1996); Ellison and Ellison (2009); Ellison and Wolitzky (2012). Motivated by the rise of the Internet, clearing-house models tend to de-emphasize the role of consumer search costs, but the frameworks are to some extent isomorphic (Baye, Morgan, and Scholten, 2006).



general message in a context where homing behavior is determined endogenously in equilibrium through firm-listing and consumer-search decisions.

Other recent contributions allow sellers and buyers to conduct business off-platform in markets where products, and often platforms, are differentiated. There, models such as Edelman and Wright (2015) show that platforms may over-invest in various buyer-side benefits in the presence of price-parity clauses. Wang and Wright (2019) study “show-rooming” and assume platforms ease the comparison of products. In contrast, I model a homogeneous-good market, isolating price as the determinant of consumer welfare, where the benefit that a platform brings is purely informational: it lists available prices. The potential benefit of a PCW to consumers is that it can lower prices via the interaction of strategic, competing firms who choose to list their prices there. Any benefit offered by the platform is therefore determined endogenously via the equilibrium actions of firms and consumers. Furthermore, as opposed to models that exogenously assume a benefit for buyers from using the platform, my model endogenously produces the rationale for consumers to use it: prices in the marketplace are dispersed.

Perhaps the most well-known point from the two-sided markets literature is that platforms tend to charge more to one side of the market in order to subsidize the other. In the markets relevant to my work, PCWs typically charge firms high commissions while offering free access to consumers. In the equilibrium of my model consumers single-home while firms multi-home, which indeed makes consumers the valuable side of the market for PCWs to attract. Through a series of extensions, I evaluate how inter-PCW competition may best be spurred. My first exercise makes the novel point that a policy mandating transparency of the fee paid by firms to aggregators can improve outcomes for consumers, but relies on unrealistic consumer coordination.<sup>9</sup> I next show how PCW-competition in variables on the buyer-side of the market can lead to competitive outcomes more naturally. Policy-relevant work relating to these markets has largely focused on how to create an environment in which *firms* are as free as possible to compete in price. For example, much attention has been paid to so-called most-favored-nation or price-parity clauses, e.g., Boik and Corts (2016); Johnson (2017); Edelman and Wright (2015); Johansen and Vergé (2016); Wang and Wright (2019). In contrast, my findings provide the more general perspective that for policy to create a competitive environment in the relevant markets, it should focus on facilitating PCW-competition over variables such as PCW-funded discounts that can *directly* reduce the price paid by consumers, rather than measures that affect consumers *indirectly* such as commissions.

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<sup>9</sup>In more traditional vertical markets with consumer search, Janssen and Shelegia (2015) show that consumer uncertainty over the prices paid by retailers to wholesalers exacerbates the double-marginalization problem.

### 3 Model and Equilibrium

**Model without PCWs.** There are  $n > 2$  firms and a unit-mass of consumers. Firms produce a homogeneous product at the same marginal cost that is (without loss of generality) normalized to zero, without capacity constraints or fixed costs. Each consumer demands one unit with a willingness to pay of  $v > 0$ . A proportion  $\alpha \in (0, 1)$  of consumers are “active” and  $1 - \alpha$  are “inactive”. Each consumer is endowed with a “default” firm whose price they know. Inactive consumers simply buy from their default firm (provided the price does not exceed  $v$ ). There is a single time period in which firms and consumers play a simultaneous-move game: each firm sets a price and each active consumer sets their search strategy.

I assume active consumers conduct “fixed-sample” search: they choose which websites to visit given their beliefs over prices. They then visit their chosen websites, and buy at the lowest price they find (provided it does not exceed  $v$ ).<sup>10</sup> Active consumers may also not be ex-ante aware of every firm in the market. To model this, I assume they are aware of a random subset of  $q \in \{2, \dots, n\}$  firms (their default firm and  $q - 1$  others). To discover the price of a firm they are aware of other than their default, an active consumer must visit that firm’s website (if they do not search a firm they are aware of they do not learn its price, but have correct expectations in equilibrium). Active consumers’ first visit to a (non-default) firm is free and always made. For the second visit and beyond, they incur a small but positive marginal search cost,  $\epsilon \approx 0$ .

I seek Nash equilibria in which firms adopt symmetric pricing strategies and active consumers adopt symmetric search strategies. Going forward I refer to these simply as equilibria.

**Discussion of assumptions.** The dichotomous consumer type-space captures the presence of savvy consumers who shop around, and those less active. Inactive consumers can also be thought of as “auto-renewing”, “loyal”, or “offline”. Due to e.g., high search or switching costs, inertia, brand loyalty, or a lack of information, they simply buy from their default firm. In markets where firms are service providers, these consumers allow their contract with their existing provider to continue. Much of the furore surrounding PCWs has been directed at those operating in the services and utilities sectors.<sup>11</sup> In the presentation that follows I adopt terminology suited to that sector, with inactive consumers referred to as “auto-renewers”.

That consumers are informed of the price of a default, “current” or “preferred” firm has many natural interpretations. In a market for services or utilities, e.g., gas and electricity tariffs, mortgages, credit cards, broadband, cellphone contracts, car, home and travel insurance etc., consumers can be thought of as having a current provider for the service whose current and

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<sup>10</sup>Note that because these latter actions (visiting and buying) are non-strategic, a one-stage game is sufficient for analysis. Where there is a tie in the lowest price any interior tie-breaking rule may be assumed.

<sup>11</sup>Through a comparative analysis, Antal (2020) argues privately-run energy PCWs harm consumers.

renewal price they know.<sup>12</sup> In markets for flights, hotels or durable goods, consumers can be thought to have a carrier, hotel, or seller that they prefer or use regularly, perhaps via a bookmark in their browser or a familiar app.

The assumption of “fixed-sample” search simplifies analysis and often describes behavior well. For example, De los Santos, Hortaçsu, and Wildenbeest (2012) and Honka and Chintagunta (2016) examine data from markets for books and car insurance, respectively, and fail to find a relationship between the prices consumers see and their decision to continue searching.

That consumers’ first visit is free and always made is a common assumption in the search literature. Because consumers also know their default firm’s price, the assumption implies at least two prices are seen, which avoids the Diamond paradox where all prices are the monopoly price and no consumers search.

I assume search costs to be small, which best suits the applied setting. For example, consumers must incur the cost of opening a tab in a browser and entering some basic information such as their address or credit card details. When prices are dispersed and there is no PCW, this assumption leads consumers to search up to their information constraint i.e., consumers learn the prices from all the  $q$  firms they are aware of. The assumption simplifies matters and is not critical. For example, in the case of large search costs (e.g.,  $\epsilon > v$ ) consumers are unwilling to gather a third price, and the analysis follows the case of  $q = 2$ .

**A world without PCWs.** The setup corresponds to that of a classic clearing-house model, a seminal example of which is Varian (1980).<sup>13</sup> A central result of these models is that they produce equilibrium price dispersion by firms pricing via continuous mixed strategies.

Here I outline how the equilibrium is derived (details are found in the Appendix). Let  $F_q: p \rightarrow [0, 1]$  denote the cumulative distribution function of prices charged by firms. Because active consumers always compare at least two prices, the firms’ equilibrium pricing strategy cannot feature any mass points. If it did, there would be a positive probability of a tie at the lowest price, and a firm could profitably deviate by shifting the probability mass placed on the tie to slightly below the tie (generating a discrete gain in sales at an arbitrarily small loss in price). Because  $F_q$  is continuous, all prices are distinct with probability one, and in equilibrium, search costs are sufficiently low such that active consumers will search the firms they are aware of. Proposition 1 presents the equilibrium without a PCW.<sup>14</sup>

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<sup>12</sup>Providers usually provide renewal price information directly to their consumers.

<sup>13</sup>Varian motivates the two consumer types as being completely informed about all  $n$  prices, or uninformed of all but one price. In my model’s unique equilibrium, active consumers are informed of  $q \in \{2, \dots, n\}$  prices. When  $q = n$ , Varian’s equilibrium corresponds to that derived in Proposition 1 below. Some differences from Varian are that I assume zero costs and do not employ his zero-profit condition. For related results with simultaneous consumer search, see Burdett and Judd (1983); Janssen and Moraga-González (2004).

<sup>14</sup>Distribution (1) is the only symmetric equilibrium. When some consumers compare exactly two prices (e.g.,

**Proposition 1 (Equilibrium without PCWs).** *There is a unique equilibrium in which active consumers are aware of  $q \geq 2$  prices and firms mix according to the distribution*

$$F_q(p) = 1 - \left[ \frac{(v-p)(1-\alpha)}{qp\alpha} \right]^{\frac{1}{q-1}} \quad \text{for } p \in \left[ \frac{v(1-\alpha)}{1+\alpha(q-1)}, v \right]. \quad (1)$$

Price dispersion is a key feature of clearing-house models. In my context, the dispersion provides an economic rationale for the existence of price comparison websites. Models that introduce a profit-maximizing clearing-house assume that without it consumers cannot check other prices i.e.,  $q = 1$ , so the pure monopolistic-price equilibrium of  $p = v$  results. I obtain that equilibrium if  $\alpha = 0$ ; and if  $\alpha = 1$ , the Bertrand outcome of  $p = 0$  results. As in Stahl (1989), the equilibrium CDF of (1) converges continuously to these outcomes as  $\alpha \rightarrow 0$  and  $\alpha \rightarrow 1$ , respectively. Here, unlike Stahl, active consumers do not necessarily know the prices of all firms, but they know at least two, which is sufficient for price dispersion to emerge in equilibrium.

It is also instructive to note that equilibrium pricing does not vary with the number of firms,  $n$ . Each active consumer compares  $q \geq 2$  prices, regardless of the total number of firms. Because all firms price symmetrically and independently in equilibrium, it is as if each firm only faces  $q - 1$  rivals. When choosing price, a firm is not concerned about the number of other firms per se, but rather about the number of other prices consumers know. In other words, what matters is the number of comparisons consumers make, not the number of firms in the market.

**Model with PCWs.** Suppose now that  $K > 1$  price comparison websites indexed  $k = 1, \dots, K$  exist. I add a preliminary stage to the game at which each PCW sets a commission rate  $c_k$  that a firm must pay to the aggregator per sale made via the site. Firms first observe the commission rates  $\{c_1, \dots, c_K\}$ , and then choose their price and which PCWs to post it on. Consumers do not observe commissions (but all players have correct expectations in equilibrium). Active consumers can visit any combination of websites, firms' or PCWs. To summarize:

t=1 PCWs set commission.

t=2 Firms observe commission rates, choose price and which PCWs to list it on; active consumers choose which websites to visit.

I seek symmetric Nash equilibria in which PCWs set a symmetric fee level and at least some consumers visit PCWs, which are not found empty on the equilibrium path. I also assume two tie-breaking rules that were irrelevant without PCWs. First, in the case that a consumer's cheapest price is their default firm, the consumer does not switch. Second, if the cheapest price a consumer sees is not charged by their default firm, and the consumer sees it on both a PCW and that firm's website, the sale takes place directly with the firm.

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$q = 2$ ), Johnen and Ronayne (2020) prove the symmetric equilibrium is the unique equilibrium. Otherwise (e.g.,  $q > 2$ ), they show that although there are many asymmetric equilibria, only the symmetric equilibrium is stable.

**Discussion of assumptions.** Flat per-unit commission is often used in practice, for example and as reported by the BBC, “[PCWs receive] a flat fee every time a customer buys a policy, and that these fees are “completely independent” of policy price”.<sup>15,16</sup> I assume firms are aware of the commission they will hand to the PCW in return for a sale, but that consumers are unaware. As the quote in the Introduction notes, the commission rate is “kept confidential”, not publicly announced. Later I investigate the impact of publicly announcing fees.

Looking for equilibria in which at least some consumers visit PCWs which are not found empty on the equilibrium path precludes trivial and implausible outcomes. It rules out, for example, the trivial equilibrium in which no firm lists their price on any PCW and no active consumer checks any PCW, so that we are in effectively in the world without PCWs.

The tie-breaking rules lead to natural on-path play in the relevant markets when a consumer discovers their default firm is the cheapest. In services and utilities markets, these consumers take no further action and let their contract renew with that provider. In the travel reservations market, a consumer may be most familiar with their default firm, or may need take no further action instead allowing a secretary, colleague or friend to book directly with that firm. Note that these are the most unfavourable tie-break rules for PCWs.

**A world with PCWs.** With a monopolist PCW, I find a unique equilibrium in which: the PCW charges a positive commission level; prices are dispersed; firms list their price on the PCW; and active consumers search only the PCW. I now explain how the equilibrium is derived.

For an equilibrium not to feature an empty PCW on the equilibrium path, firms list their prices there. In turn, active consumers visit only the PCW (single-home) where they compare the whole market of  $n$  prices, rather than individual firm websites that reveal one price each. Now consider firms’ pricing strategy at  $t = 2$  following the PCW’s choice of commission,  $c$ , at  $t = 1$ . Suppose first that some sales go through the PCW in equilibrium. Then pricing must be in mixed strategies (if it were in pure strategies, then at some price  $p$ , all consumers buy directly from their default firm and no sales go through the PCW). Therefore, any price charged in equilibrium is the cheapest on the market with positive probability. As in the world without a PCW, consumers compare multiple prices so firms’ strategy has no mass points (firms would shift probability slightly below any such point), and the support of prices is an interval (firms would shift probability from slightly below, to the top of, any gap). Denote the pricing strategy by the distribution function  $G(p; c)$ . The maximum of the equilibrium support must be  $v$  (if lower, firms could do better by moving probability from around the maximum to  $v$ ) and firms

<sup>15</sup>BBC (2013), <http://www.bbc.co.uk/news/business-25068588>.

<sup>16</sup>In a clearing-house setting, Baye, Gao, and Morgan (2011) allow for any two-part tariff (consisting of fixed and per-unit components) to be set and show that a profit-maximizing PCW would optimally set the fixed component to zero. In some markets, the per-unit fee is ad valorem. For example, comparison sites in the travel reservation industry tend to charge percentage fees. In Appendix C, I show that my main result holds with ad valorem fees.

must be indifferent between  $v$  and any other price in the support,  $p$ :

$$v(1 - \alpha)/n = p(1 - \alpha)/n + [p + (n - 1)(p - c)](1 - G(p; c))^{n-1}\alpha/n \quad (2)$$

$$\Leftrightarrow G(p; c) = 1 - \left[ \frac{(v - p)(1 - \alpha)}{\alpha(np - (n - 1)c)} \right]^{\frac{1}{n-1}}, \quad (3)$$

a well defined CDF over support  $[\underline{p}, v]$ , with  $\underline{p} = v[(1 - \alpha) + c\alpha(n - 1)]/[1 + \alpha(n - 1)]$ . It remains to check that firms indeed want to list any price in the equilibrium support, i.e., that  $\underline{p} \geq c$ . Rearranging terms shows that  $\underline{p} \geq c \Leftrightarrow c \leq v(1 - \alpha)$ . Therefore, when  $c$  is relatively small, equilibrium prices are dispersed. When setting prices, firms trade off their incentives to charge higher prices to exploit their inactive consumers and to charge lower prices to win over active consumers. Key differences from the world without a PCW are that the incentive to win active consumers is heightened because firms compete for all active consumers, but it is dampened by the PCW's commission.

To complete the characterization, I now look for equilibria in which no sales go through the PCW. Because active consumers check the PCW, this is only possible when there is no price dispersion i.e., firms price in pure strategies, so that all consumers buy from their default providers: the market for switching shuts down. For one price,  $p^*$ , to be part of an equilibrium, firms must not wish to deviate. Profit under  $p^*$  is  $p^*/n$ . It must be that  $p^* \leq c$ , else a firm could list a slightly lower price and profitably win its rivals' active consumers. Deviations to  $p < p^* \leq c$  reduce profit from a firm's own customers and make a loss on any consumers won. Deviating to a higher price generates sales only to auto-renewers, so the optimal such price is  $v$ , yielding profit of  $v(1 - \alpha)/n$ . Such a deviation is not profitable when  $p^* \geq v(1 - \alpha)$ . In sum, the price  $p^* \in [v(1 - \alpha), c]$  is a best response for firms when  $c \geq v(1 - \alpha)$ . Lemma 1 summarizes.

**Lemma 1 (Firms' pricing in t=2).** *Firms' prices as a function of  $c$  are as follows:*

*if  $c \in [0, v(1 - \alpha))$ , firms price according to  $G(p; c)$ ;*

*if  $c = v(1 - \alpha)$ , either firms price according to  $G(p; c)$ , or firms all charge the price  $p = c$ ;*

*if  $c \in (v(1 - \alpha), v]$ , all firms charge the same price,  $p \in [v(1 - \alpha), c]$ .*

The responses of firms to the PCW's choice of commission are dichotomous. Following a commission rate below the threshold  $v(1 - \alpha)$ , firms find it worthwhile to fight for active consumers by undercutting their rivals until they find it more profitable to give up and charge only their auto-renewers at the monopoly price. Following fees above the threshold, prices above the fee are still undercut, but the high commission means that prices do not reach the point at which firms give up competing for active consumers to sell only to auto-renewers at the monopoly price. For fee levels in this range, firms do better than under the mixed-strategy pricing that followed lower fees, and their profits increase with the fee. In this sense, firms free-ride on a high commission rate and the market consists only of uncontested high prices.

Now consider the PCW's choice of  $c$ . The PCW makes zero profit if firms price in pure-strategies because no consumers switch. In contrast, the PCW earns positive profit when prices are in mixed-strategies and  $c > 0$ . The PCW therefore has an incentive to induce price dispersion, which prompts switching. A feature of continuous distributions is that the probability of a tie in price is zero. As a result, active consumers at  $n - 1$  of the  $n$  firms will switch. Given that firms mix in this way, the PCW makes a profit of  $c\alpha(n - 1)/n$  and so will raise  $c$  as high as possible such that prices are dispersed i.e., to  $c = v(1 - \alpha)$  (by Lemma 1).<sup>17</sup>

With  $K > 1$  PCWs, the commission level and prices are unchanged in equilibrium. To see why, consider the strategies of players at  $t = 2$ . PCWs are not found empty so firms must list their prices ubiquitously. Therefore, active consumers visit exactly one PCW, which, in turn, provides firms with the incentive to list ubiquitously (else some consumers would not see their price). Given a symmetric choice of fee level at  $t = 1$ , firms' pricing incentives are therefore the same as when there is a monopolist PCW, and their best responses follow those of Lemma 1.

It remains to check that at  $t = 1$  no PCW deviates from any candidate symmetric equilibrium fee level,  $c$ . There is no profitable unilateral deviation down in fee level: each PCW serves  $1/K$  active consumers who check no other website; any reduction in fee level would reduce income without increasing the sales (the  $K$  PCWs are essentially  $K$  co-existing monopolies). However, if  $c < v(1 - \alpha)$ , a PCW can unilaterally raise its fee level slightly above any potential symmetric equilibrium level without losing any sales: firms will still list their prices on the deviator's site because, although they will pay slightly more in commission, de-listing would entail losing exposure to the  $1/K$  active consumers attending it. Therefore, the unique equilibrium fee level with any number of PCWs is  $c = v(1 - \alpha)$ . Proposition 2 reports the equilibrium.<sup>18</sup>

**Proposition 2 (Equilibrium with PCWs).** *There is a unique equilibrium in which PCWs set a fee of  $c = v(1 - \alpha)$ ; firms list on all PCWs and mix over prices according to  $G(p; v(1 - \alpha))$  with support  $p \in [v(1 - \alpha), v]$ ; and active consumers visit exactly one PCW.*

The PCW's fee is limited to  $v(1 - \alpha)$  in equilibrium. The reason is the outside option of firms: a firm can always sell to its own active consumers without paying the aggregator's fee by charging a price low enough to undercut all others, and not posting it on the PCW. It is this advantage that allows firms to free-ride on higher commission levels. Reducing this outside option would therefore lead to higher equilibrium commission. In an extreme case, if firms did not have their own consumers, the PCW could raise its fee to  $c = v$ , firms would charge  $p = v$ , price dispersion would be lost and the PCW would extract all surplus.

<sup>17</sup>Lemma 1 states that pure or mixed pricing strategies can follow  $c = v(1 - \alpha)$ . However, prices cannot be in pure strategies: if so, the PCW would prefer to charge a fee slightly below  $c = v(1 - \alpha)$  to induce firms to mix.

<sup>18</sup> In this symmetric equilibrium, all firms list on the PCW. In practice, although PCWs are not empty, some firms do not always list on PCWs. In my model, there exist asymmetric equilibria in which  $m \geq 2$  firms list on the PCW and mix over prices  $[v(1 - \alpha), v]$ , while  $n - m$  do not list, charge  $v$  and sell only to their auto-renewers, and active consumers visit only the PCW. My main results extend to any of these asymmetric equilibria.

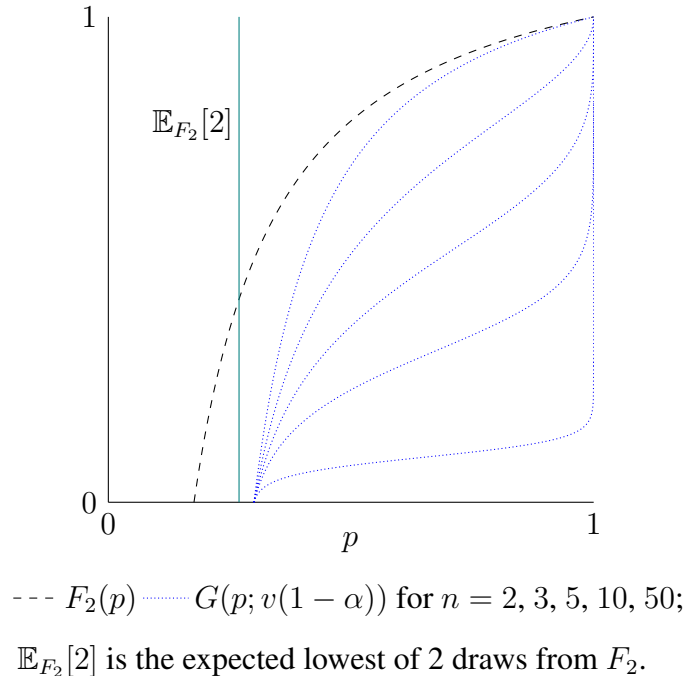
## 4 Comparative Statics

Comparing Propositions 1 and 2 reveals how PCWs affect consumers. The game is constant sum. Firms make the same equilibrium profit with or without PCWs because in either world they compete away profit from active consumers so that sales to their inactive base (which they can always monopolistically exploit) determine their payoff. When PCWs exist they make positive profits. Together, these observations show consumers lose out on average with PCWs in the market. The one-to-one relationship between total consumer- and PCW-surplus showcases the stark tension between these actors, demonstrating how consumers carry the burden of PCWs. Building on this, my main result reports the effect of PCWs on each consumer type.

**Proposition 3.** *Both types of consumer are worse off with PCWs than without.*

The result says that from the perspective of any consumer, any pro-competitive effects of a PCW are outweighed by price-raising effect of the fee. The key to the proof is to show that the expected price paid by active consumers under  $F_q$  is *less* than the *lower bound* of the support of  $G^* \equiv G(\cdot, v(1 - \alpha))$ ; Figure 1 presents an illustration. It then follows that the expected price active consumers pay is higher under  $G^*$ . That  $G^*$  first-order stochastically dominates  $F_q$  shows that auto-renewers expect to pay more under  $G^*$ , because the expected price is higher.

Figure 1: Equilibrium price distributions calibrated with  $q = 2$ ,  $v = 1$ ,  $\alpha = .7$



To unpack the result, I show that the introduction of a market of PCWs has two effects, detailed in Corollaries 1 and 2:

**Corollary 1.** *Within the mixed-price equilibrium firm responses of Lemma 1, as  $c \in [0, v(1 - \alpha)]$  increases, the expected price paid by both types of consumer increases.*



**Corollary 2.** *As the number of firms increases, the expected price paid by active consumers falls, but the expected price paid by auto-renewers rises.*

Corollary 1 shows that when PCWs set higher fees, the expected price paid by both active consumers and auto-renewers rise. This follows because commission is passed on by firms to consumers through a first-order stochastic shift in the distribution of prices set in equilibrium i.e.,  $G(p; c)$  is FOSD-ordered in  $c$ .

The second effect is that PCWs increase competitive pressure among firms who fight for all of their  $n - 1$  rivals' consumers. In contrast, without the PCWs, firms effectively competed against only  $q - 1$  rivals. An increase in  $n$  has two effects on equilibrium prices. First, increased competition pushes equilibrium probability mass to the right extreme of the pricing distribution, as Figure 1 shows. This results in a first-order stochastic ordering in  $n$ : expected price thus increases in  $n$  and auto-renewers pay more. Second, active consumers now pay the lowest of  $n + 1$  prices rather than  $n$ , which reduces the expected lowest price. Corollary 2 reveals that this second effect more than offsets the first, implying that active consumers pay less in expectation when there are more firms.<sup>19,20</sup>

To relate these two effects of a PCW to Proposition 3 more directly, note that  $G(p; 0) = F_n(p)$ . The entrance of PCWs increases both the fee firms pay, from 0 to  $v(1 - \alpha)$ , and the number of prices that active consumers compare, from  $q$  to  $n$ . The first effect raises the expected price auto-renewers pay, which is compounded further by  $n \geq q$ , so they are unambiguously worse off with a PCW. The effects pull active consumers' welfare in opposite directions, but Proposition 3 shows that no matter how large  $n$  is, it fails to undo the effect of the equilibrium commission level. Hence, active consumers are also worse off in expectation with a PCW.

One channel through which all consumers would gain is by more auto-renewers becoming active consumers, as reported by Corollary 3. It follows because  $G(p; c)$  is FOSD-ordered in  $\alpha$ . This prediction is common to clearing-house models for which Morgan, Orzen, and Sefton (2006) find experimental support. The effect is termed a “search externality” by Armstrong (2015) and it arises because firms compete more fiercely when the proportion of savvy consumers is higher, which benefits both types of consumers.

**Corollary 3.** *As the proportion of active consumers,  $\alpha$ , increases, the expected price for both types of consumer decreases.*

<sup>19</sup>Clearing-house models offer different predictions about the effect of  $n$ . Some predict increasing  $n$  raises prices for both types of consumer (e.g., Rosenthal, 1980); others predict it lowers prices for active consumers and raises them for captive consumers (e.g., Varian, 1980); see Janssen and Moraga-González (2004, Footnote 11) and Baye, Morgan, and Scholten (2006) for a discussion of this point. My model belongs to this second category.

<sup>20</sup>Corollary 2 is common to clearing-house models, but may seem a nuanced prediction. Morgan, Orzen, and Sefton (2006) conduct an experiment with participants playing the role of firms against computerized buyers and found that when  $n$  was increased, prices paid by inelastic (active) consumers indeed increased (decreased).

One may then conjecture that a PCW would want to maximize  $\alpha$  in order to obtain more referral fees. However, this logic is incomplete. Considering the case of a single PCW and expanding its action set to include the determination of  $\alpha$  (e.g., through advertising) yields the following:

**Corollary 4.** *If a monopolist PCW sets  $\alpha$  as well as  $c$  at the preliminary stage,  $\alpha = 1/2$ .*

PCW revenue is hump-shaped in  $\alpha$ . As  $\alpha \rightarrow 0$  traffic, and hence revenue, vanish. As  $\alpha \rightarrow 1$ , firms have fewer auto-renewers to exploit, pushing  $v(1 - \alpha)$ , the maximum fee for which firms are willing to mix, to zero. Indeed, when  $\alpha = 1$  there are no auto-renewers and the PCW removes any incentive for firms to increase prices. As a result, all firms charge the same price and no active consumers switch providers, leaving no scope for PCW profits. Thus, even if the PCW could make all consumers active, it has a strict incentive not to.

In models where firms are responsible for price advertising (e.g., Ireland, 1993; McAfee, 1994), one distinct firm advertises the most and all others inform at most half of buyers. Firms are of course responsible for advertising their own price only. By Corollary 4, I show that a PCW responsible for all prices would only wish for a minority of buyers to be aware of prices market-wide (a strict minority where advertising is costly).

**Robustness.** My main result also emerges under a variety of alternate assumptions, including “firm-led” price discrimination, ad valorem PCW fees, the presence of meta-sites, and when there is search at the extensive margin (details and proofs are provided in Appendix B).

In the first instance, I let each firm set different prices on each PCW and their own website, while in the second, I assume that commission is a proportion of the sale price, rather than a fixed per-unit cost. In both these settings, although equilibrium prices differ from those of Proposition 2, I show they too leave all consumers worse off with PCWs.

Third, I show that meta-sites, which can host both the prices listed on firm websites and those on PCWs, are a replication rather than a solution to the problem: active consumers visit only the meta-site which hosts all prices and charges commission that PCWs pass on to firms who, in turn, pass on to consumers. Equilibrium meta-site commission is the same as that charged by PCWs in Proposition 2 and firms price via  $G(p; c)$ , so Proposition 3 follows.

Finally, I endogenize the composition of consumers in the market by assuming that auto-renewers face heterogeneous search costs as their barrier to being active. The effect of a PCW’s introduction on the distribution of prices then determines how many inactive consumers remain inactive versus how many choose to become active, a group I term “converts”. Whether the introduction of a PCW raises prices for the different types of consumers depends on how many converts there are, and thus on the search-cost distribution. However, I show that a PCW can still raise prices for all consumers, *including converts*.

## 5 Stimulating Inter-PCW Competition

The preceding analysis showed how the arrival of an industry of PCWs can raise the expected price faced by all consumers, regardless of whether they use the sites. Against this backdrop, I consider a series of extensions to identify both the less- and more-promising directions for policy to foster a more competitive environment in these markets.

The exercises introduce publicly observable actions taken by PCWs at  $t = 1$ . Because these actions are observed by both firms and consumers, they present the opportunity for consumers to coordinate their search decisions based on PCWs' choices. As the equilibrium of Proposition 2 highlighted, firms tend to multi-home while consumers single-home. Therefore, any convincing requirement for coordination to stimulate inter-PCW competition is that the single-homing side, consumers, coordinate on the variable by which PCWs compete. To investigate the potential for consumers to benefit from the industry, in each case I make a coordination assumption that is both simple and most-beneficial to consumers.

**Fee transparency.** In reality, PCW fees are not publicized directly and, as the quote in the Introduction states, tend not be publicly available at all. Some competition authorities have emphasized that PCWs should be generally transparent regarding the mechanisms by which they make money (e.g., CMA, 2017b, paragraph 1.18). Here, I consider the effect of introducing fee-transparency into the model and examine its impact on inter-PCW competition.<sup>21</sup>

Suppose the commissions chosen by competing PCWs are publicly announced and that active consumers “profitably coordinate on commission”, meaning they only visit PCWs that charge firms the lowest commission. Profitable coordination on commission is beneficial to consumers because lower fees translate into lower prices (Corollary 1). Under such coordination PCWs have a strong incentive to undercut each other's fees.

In the subgame perfect equilibrium active consumers coordinate on attending the PCWs charging the lowest fee and all firms list there. At  $t = 1$ , no positive commission level can be part of an equilibrium because it is unilaterally undercut, so that the only such equilibrium fee is  $c^* = 0$ . Equilibrium prices are given by  $G(\cdot, 0)$ , firms list ubiquitously and consumers visit exactly one PCW. In this equilibrium, active consumers benefit from the existence of PCWs. When active consumers profitably coordinate on access fees, this equilibrium is unique except for trivial differences in firm listing.<sup>22</sup>

In contrast, such an equilibrium was not possible when fees were hidden because consumers cannot detect, and therefore cannot react to, any deviations of PCWs from the equilibrium

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<sup>21</sup>With a single PCW there is of course no inter-PCW pressure and the equilibrium of Proposition 2 persists.

<sup>22</sup>In subgames starting at  $t = 2$  following asymmetric fee profiles, it is irrelevant whether firms list on PCWs charging a fee  $c > \min_k \{c_k\}$ , where no sales take place, generating a trivial multiplicity.

commission level. Fee-secrecy therefore precludes coordinated responses between consumers that could punish high-commission PCWs.

**Access fees.** In practice, PCWs do not generally charge consumers for their services and my model has so far ignored the ability of PCWs to profit directly from the buyer-side of the market. Now suppose that each PCW  $k = 1, \dots, K$  sets a fixed access fee,  $b_k \geq 0$ , that consumers must pay in order to reveal the prices it hosts. Access fees are set at  $t = 1$  at the same time it chooses the commission level paid by firms, and is observed by both firms and consumers.

First consider the case of a single PCW's choice of access fee,  $b$ . Because the access fee is lump-sum and sunk by active consumers before they compare prices, given active consumers' strategy, access fees do not affect firms' pricing incentives. Because  $b$  is an additional cost to active consumers, it follows that in any equilibrium featuring PCW use and access fees, my main comparative static result (Proposition 3) stands and all consumers face higher prices with PCWs than without. In equilibrium, the PCW can raise  $b$  until the point that active consumers are indifferent between accessing the PCW and abandoning it to instead search the websites of the firms they are aware of (consumers' outside option). Equilibrium otherwise corresponds to Proposition 2 (see Appendix C for details). A monopolist PCW is therefore able to profit from both sides of the market, extracting information rent from consumers.

Now consider the case of multiple PCWs and assume that active consumers "profitably coordinate on access fees", meaning they only visit PCWs that charge firms the lowest access fee. Profitable coordination on access fees is beneficial to consumers because it reduces the amount of information rent extracted from them. Under such coordination PCWs profitably undercut the lowest access fee charged by a competitor because doing so attracts all active consumers.<sup>23</sup> Therefore, competition in access fees yields  $b_k^* = 0$  for all  $k$ . The equilibrium otherwise corresponds to Proposition 2. Proposition 4 summarizes.

**Proposition 4 (Access fees).** *With  $K > 1$  PCWs, there is an equilibrium in which PCWs set access fees of  $b^* = 0$  and strategies are otherwise those of Proposition 2. In this equilibrium, both types of consumer are worse off with PCWs than without. When consumers profitably coordinate on access fees, this equilibrium is unique save for trivial differences in firm listing.*<sup>24</sup>

In reality, buyer-side fees are mostly absent from the markets under consideration, and so my analysis suggests that competition is largely successful on this dimension. That said, the prediction that the introduction of a market of any number of profit-maximizing PCWs raises prices for all consumers is unaffected. This is because access fees are an additional slice taken from

<sup>23</sup>If the lowest access fee charged by a competitor surpasses the monopolist's equilibrium choice of access fee ( $b^*$  of Proposition C1), there are no best responses at  $t = 2$  with PCW use and Proposition 1 applies. Thus, in this case the most profitable such undercut is to  $b^*$ .

<sup>24</sup>In subgames starting at  $t = 2$  following asymmetric fee profiles, it is irrelevant whether firms list or not on PCWs charging access fees that are not the lowest, where no sales take place, generating a trivial multiplicity.

consumer welfare on top of that of my earlier analysis. If access fees could be negative, so that consumers are paid to visit PCWs, then competition between PCWs could potentially allow at least active consumers to benefit from the industry. However, the moral hazard issue arising from offering subsidies for visits presumably precludes this from occurring in practice. This could be overcome if such negative buyer-side fees were made conditional on a consumer completing a purchase through the associated PCW. Such payments are functionally equivalent to PCW-funded discounts of the retail price. I consider these next.

**PCW-led price discrimination.** In some markets the price differs according to whether consumers buy through a PCW or directly through a firm’s website. This can either occur because firms set different prices for sales made through the two channels (discussed in the robustness exercises of Comparative Statics) or where firms set one price but PCWs offer their own discounts to consumers, a practice I term “PCW-led price discrimination”. This latter possibility allows PCWs to compete for consumers with a variable that directly affects the price they pay.

In practice, discounts offered by PCWs take various forms e.g., explicit discounts, free shipping, gift vouchers, etc. My primary analysis implicitly imposed that such discounts were zero. However, if PCWs chose a discount contemporaneously with firms’ choice of price at  $t = 2$ , PCWs face a commitment problem: in any candidate equilibrium with positive discounts they would have an incentive to reduce their discount. Therefore, in order for discounts to have a meaningful impact on outcomes I suppose that PCWs can commit to discounts, which are set at  $t = 1$ . Formally, at  $t = 1$  I allow each PCW  $k = 1 \dots K$  to set a per unit discount to consumers for any purchase made through their site,  $d_k \geq 0$ , funded by PCW  $k$  and observed by consumers. Therefore, the effective price paid by an active consumer for a product sold at price  $p$  on PCW  $k$  is  $p - d_k$ .

First consider the setting with one PCW that sets  $(c, d)$  at  $t = 1$ . The PCW sets  $d > 0$  because this gains the sales from firms’ own active consumers. In equilibrium, the PCW sets the lowest discount it can such that firms find it unprofitable to de-list and undercut the discounted prices it hosts. Subject to this constraint, the PCW raises commission as high as possible, resulting in the equilibrium choices  $(c^*, d^*) = (v, v\alpha)$ , while firms price at  $v$  (see Appendix C for details). The PCW makes  $c^* - d^* = v(1 - \alpha)$  per sale, as it did in the setting without discounts (Proposition 2). That is, the PCW’s commission completely compensates it for the discounts it uses in order to ensure it sells to all active consumers. Regarding prices, auto-renewers pay  $v$ , while active consumers pay the discounted price of  $v(1 - \alpha)$ . Although the latter is less than what active consumers paid in the setting without discounts, Proposition 2, it is equal to the lower bound of prices there and hence all consumers are worse off with the PCW.

With multiple PCWs and discounts I assume active consumers “profitably coordinate on discounts”, meaning that following a profile of discounts by PCWs at  $t = 1$ , they only visit PCWs

offering the highest discount. Such coordination implies that PCWs make zero profit when they do not offer the highest discount, and so  $d_k$  is competed up to the point that PCW profit is zero i.e.,  $d_k = c_k$ ; and to loosen this constraint as much as possible, PCWs raise  $c_k$  to  $v$ .<sup>25</sup> Proposition 5 reports the equilibrium.

**Proposition 5 (PCW-led discrimination).** *With  $K > 1$  PCWs, there is an equilibrium in which PCWs set a fee of  $c^* = v$  and a discount of  $d^* = v$ ; firms list a price of  $v$  on all PCWs such that active consumers pay the effective price of zero. Active consumers visit exactly one PCW, and benefit from the existence of PCWs. When consumers profitably coordinate on discounts, no other choices of commission, discount or price can result in equilibrium.*

**Discussion.** In my model, competing PCWs do not assert downward pressure on commission levels relative to a monopolist PCW (Proposition 2). As a result, the introduction of PCWs into a market can raise prices and harm consumers, regardless of whether they use the sites (Proposition 3). Therefore, when the introduction of profit-maximizing PCWs into a market is itself a policy, it may harm consumers. As such, for markets where price is the variable of primary concern there is a case for regulators to consider more heavy-handed measures such as capping fees or providing a publicly-run site in order to impose a lower-commission environment.<sup>26</sup> However, such measures may carry potentially adverse effects outside the scope of my model. The series of extensions I investigated in this section allow identification of policies and practices better placed to stimulate competition in the price-comparison industry. Specifically, I showed how competitive (zero-PCW-profit) outcomes can obtain via competition on the seller- and buyer-side of the market.

On the sellers' side, I demonstrated that a policy of fee transparency is able to deliver a competitive outcome when consumers coordinate on the PCW charging the lowest commission. However, the prediction that consumers will coordinate in this way seems questionable in reality. Even if consumers could all be informed about fees, they do not care about them *per se*, paid as they are between firms and PCWs.<sup>27</sup> As an example of this general disengagement, a study by the UK's competition authority found that consumers tended not to have thought about how PCWs make money, and drastically underestimated commission rates when asked (CMA, 2017c, paragraphs 34-35). Even supposing that such coordination were likely, other issues may render mandated commission transparency ineffectual. For example, there is evidence that consumers find commissions confusing, reducing their ability to identify the cheapest seller (in the

<sup>25</sup>Commission cannot rise above  $v$ : If  $c > v$ , for firms to sell through such a PCW, prices would be competed down to  $c$  (because only active consumers buy), so firm profit would be zero; but de-listing and selling to auto-renewers would yield a positive profit for firms.

<sup>26</sup>For an example of a publicly-run aggregator see [www.fuelwatch.wa.gov.au](http://www.fuelwatch.wa.gov.au), a government-run PCW for gasoline prices in Western Australia (discussed in Byrne, de Roos, and Tiong, 2014).

<sup>27</sup>Although fee information is generally unavailable, some PCWs advertise statistics such as the average savings a consumer using their site is expected to make, which could implicitly direct consumers to the cheapest PCW. However, many PCWs instead opt for more "persuasive" marketing strategies unrelated to price information.

context of the US mortgage market see, e.g., FTC, 2004). Furthermore, PCWs may have an incentive to obfuscate their fees e.g., in terms of jargon or complexity, so that consumers would have difficulty coordinating around it. Because consumers are not directly affected by commission, PCWs may well have more scope to do so. To restore transparency, regulation may be called upon again regarding fee presentation or structure, which could present its own issues. A more pro-active suggestion may be that a regulator or other public source announces commissions on behalf of PCWs. Beyond the question of the cost of providing such a service, one may question a policy of fee-announcements on a more fundamental level: if fees can be publicly announced then in principle so can prices, which would extinguish the role of a PCW in the first place. In sum, in pursuing the objective of stimulating inter-PCW competition, it appears unlikely that a policy mandating fee transparency would be worthwhile.

On the buyers' side, Proposition 5 showed PCW-led price discrimination delivers a competitive outcome when consumers coordinate on the PCW offering the highest discount. The analysis extended that of access fees - which are subject to a zero lower bound - by allowing PCWs to subsidize consumers. I highlighted one reason that such competition in PCW-led discrimination may not be as active in practice is that PCWs face a commitment problem, which may manifest by discounts being easy to change. In practice, (dynamic) forces such as reputation may allow some scope for commitment. Otherwise, my analysis suggests that creating an environment in which PCWs can credibly advertise discounts or other price-altering benefits carries strong potential to foster a competitive PCW marketplace. This could be achieved, for example, by targetted measures by regulators compelling PCWs that advertise such benefits transparently, and holding them to the conditions under which benefits are claimed to apply. In terms of consumer engagement, variables such as discounts are of direct pay-off relevance to consumers, which unlike commission makes them a more natural candidate to facilitate inter-PCW competition by prompting consumers to follow the PCW offering them the best discount. In the equilibrium of Proposition 5, inter-PCW pressure drove the effective price paid by active consumers to zero. In contrast, inactive auto-renewers face the monopoly price, so the gap between the prices paid by online and offline consumers, the "digital divide", is maximized. Although this maximizes the inequality of consumer outcomes, where a larger divide prompts more offline consumers to become active i.e., at the extensive margin (as discussed in the robustness exercises of Comparative Statics), all consumers can benefit.

In sum, the business model of PCWs invariably affects prices and consumer welfare. My analysis shows that consumers are harmed when they do not punish PCWs that employ potentially harmful elements such as high commissions in their contracts with sellers. Such elements: (a) are not observed by consumers; and (b) do not directly affect them. In response, there is a general and positive argument for policy to focus on fostering an environment where PCWs compete *transparently* and *directly* for consumers.

## 6 Concluding Remarks

My analysis shows that the introduction of PCWs may not in fact benefit consumers by reducing expected prices. Introduction of such sites facilitates comparison of the whole marketplace for consumers who use the sites, exerting competitive pressure on firm pricing. However, PCWs charge commissions that place upward pressure on prices. The net effect is that prices increase for all consumers, both those who use the sites and those who do not. At the heart of the issue is that consumers compare all prices on the market by visiting a single PCW in equilibrium. There is therefore no incentive for consumers to search further, effectively rendering all PCWs as monopolies with no incentive to lower their commission. The casts doubt on the fundamental assertion that the price aggregator industry necessarily benefits consumers.

My work also highlights several important forces and arguments that have not previously received much attention. First, price dispersion is a rationale for price comparison services; they have a strong, indeed existential, incentive to keep prices distinct from one another to ensure their service is valuable. Second, the mere presence of multiple PCWs is no guarantee of meaningful competition. And third, policy may better stimulate inter-PCW competition by focusing on crafting a market in which PCWs compete transparently and directly for consumers.

## Appendix A

This Appendix includes proofs, intermediate results and details omitted from the main text.

**A world without a PCW.** This section proves Proposition 1. Active consumers compare at least two prices, while inactive consumers always see exactly one price. Letting the number of prices compared by active consumers be  $z \in \{2, \dots, q\}$ , standard arguments (e.g., those in Varian, 1980) show that in equilibrium, firms mix continuously via some cdf  $F_z(p)$  over an interval support  $[\underline{s}, v]$  where  $\underline{s} > 0$ . I first take  $z$  as given, and derive the mutual best responses of firms. Because indifferent consumers do not search, this exhausts all possible equilibrium consumer behavior. Given these responses, I then show that the equilibrium value of  $z$  is  $z^* = q$ . Active consumers' search cost is assumed small. For the proofs, the bound  $\epsilon < \min\{\bar{\epsilon}, \bar{\bar{\epsilon}}\}$  is sufficient, where

$$\bar{\epsilon} = \min_{z \in \{2, \dots, q\}} \{\mathbb{E}_{F_z}[q - 1] - \mathbb{E}_{F_z}[q]\} > 0 \quad (4)$$

$$\bar{\bar{\epsilon}} = \min_{z \in \{2, \dots, q\}} \{\mathbb{E}_{F_z}[z] - \mathbb{E}_{F_{z+1}}[z + 1]\} > 0. \quad (5)$$

The term  $\mathbb{E}_{F_z}[q]$  denotes the lowest of  $q$  draws from the distribution  $F_z$  given by (6); it follows that  $\bar{\epsilon} > 0$ . That  $\bar{\bar{\epsilon}} > 0$  follows from (Morgan, Orzen, and Sefton, 2006, Proposition 3), which says that  $\mathbb{E}_F[2]$  is decreasing in  $q$ .



**Lemma A1.** *Suppose active consumers are aware of  $z \geq 2$  prices. The unique best response of firms is to mix according to the distribution*

$$F_z(p) = 1 - \left[ \frac{(v-p)(1-\alpha)}{zp\alpha} \right]^{\frac{1}{z-1}} \quad \text{for } p \in \left[ \frac{v(1-\alpha)}{1+\alpha(z-1)}, v \right]. \quad (6)$$

*Proof.* Price  $v$  is in the support of equilibrium prices, hence equilibrium profit is  $v(1-\alpha)/n$ . A firm must be indifferent between all elements of the support  $p$ :

$$v \left( \frac{1-\alpha}{n} \right) = p \left[ \frac{1-\alpha}{n} + \alpha \frac{\binom{n-1}{z-1}}{\binom{n}{z}} (1 - F_z(p))^{z-1} \right] = p \left[ \frac{1-\alpha}{n} + \alpha \frac{z}{n} (1 - F_z(p))^{z-1} \right] \quad (7)$$

The first term in the square parentheses of (7) is the profit from auto-renewers, who always purchase at  $p \leq v$ . The second term is the expected profit from active consumers given the price  $p$  is the lowest of  $z$  prices. In this case, the firm wins all  $\binom{n-1}{z-1}$  of the  $\binom{n}{z}$  groups of active consumers; the groups in which the firm's price is included. Rearranging (7), yields  $F_z(p)$  of (6) which is a well-defined CDF over  $p \in [v(1-\alpha)/(1+\alpha(z-1)), v]$ . Notice that  $v$  is strictly preferred to any  $p \in [0, v(1-\alpha)/(1+\alpha(z-1))]$ . ■

*Proof of Proposition 1.* Active consumers search all known sites:  $z^* = q$ . To prove, suppose  $z < q$ . By Lemma A1 firms price by  $F_z$ . The expected benefit of an additional search is:

$$\mathbb{E}_{F_z}[z] - \mathbb{E}_{F_z}[z+1] \geq \mathbb{E}_{F_z}[q-1] - \mathbb{E}_{F_z}[q] > \epsilon, \quad (8)$$

where the first inequality follows from a general property of first order statistics:  $\mathbb{E}_F[m]$  is decreasing at a decreasing rate for some distribution  $F$  and sample size  $m$  (see e.g., Stigler, 1961, p.215), the inequality is weak to cover the case  $z = q-1$ . The second inequality follows from (4). Because benefit outweighs cost,  $z^* = q$ .

When  $z = q$ ,  $F_q$  is the best response of firms (Lemma A1). Active consumers know of no further website to search. Also, they have no profitable deviation to search fewer sites: If  $q = 2$ , no checks are necessary; if  $q > 2$ , the expected loss from searching one fewer website is

$$\mathbb{E}_{F_q}[q-1] - \mathbb{E}_{F_q}[q] > \epsilon. \quad (9)$$

Nor are there profitable deviation to search multiple-fewer sites, e.g., for two-fewer:

$$\mathbb{E}_{F_q}[q-2] - \mathbb{E}_{F_q}[q-1] > \mathbb{E}_{F_q}[q-1] - \mathbb{E}_{F_q}[q] > \epsilon \quad (10)$$

$$\implies \mathbb{E}_{F_q}[q-2] - \mathbb{E}_{F_q}[q] > 2 (\mathbb{E}_{F_q}[q-1] - \mathbb{E}_{F_q}[q]) > 2\epsilon. \quad (11)$$

Deviations to three-or-more-fewer are handled similarly. ■

**A world with a PCW.** This section proves Lemma 1 and Proposition 2. I look for symmetric equilibria in which some consumers visit the PCW, which is not found empty on the equilibrium path. Denote  $S$  the support of equilibrium prices,  $\bar{s} = \max\{S\}$ ,  $\underline{s} = \min\{S\}$ , and equilibrium firm profit  $\pi$ . The proof holds for any  $\epsilon > 0$ . I begin by characterizing the equilibrium strategies of firms and active consumers at  $t = 2$ , following some choice of commission by the PCW at  $t = 1$ . These lead to Lemma 1. Proposition 2 for  $K = 1$  follows.

**Lemma A2.**  $\underline{s} > 0$  and  $\bar{s} \leq v$ .

*Proof.* Weakly negative prices and prices above  $v$  are strictly dominated by  $v$ . ■

**Lemma A3.** *Firms list prices and active consumers check only the PCW.*

*Proof.* If the probability that firms list on the PCW was less than one, the probability of some consumers finding the PCW empty would be positive. Because all firms list on the PCW, active consumers have a strict preference to search only the PCW. If  $S$  has more than one element, this is immediate. If  $S$  has only one element,  $p > 0$  (Lemma A2), consumers are indifferent between searching the PCW or another firm's website, but such equilibria can only exist when active consumers visit only the PCW: if consumers were to sometimes search another firm's website, firms would have a profitable deviation to slightly below  $p$  (and listing on the PCW if  $p > c$ ; de-listing otherwise), contradicting that  $S$  is the equilibrium support. ■

**Lemma A4.** *If  $c < v(1 - \alpha)$ , firms price via mixed strategies.*

*Proof.* Suppose instead  $S = \{p\}$ . Then no consumers switch; they buy directly from their default firm. Hence  $\pi = p/n$ . If  $p > c$ , firms could profit by charging a price arbitrarily-close to, but below,  $p$ . If  $p \leq c$ , a deviation to  $v$  would yield sales only to auto-renewers, making  $v(1 - \alpha)/n > p/n$ . ■

**Lemma A5.** *If  $c < v(1 - \alpha)$ ,  $\underline{s} \geq c$ .*

*Proof.* Suppose  $\underline{s} < c$ . By Lemma A4, prices in a neighborhood of  $\underline{s}$  make a loss through the PCW; firms would rather not list these prices, contradicting Lemma A3. ■

**Lemma A6.** *If  $c < v(1 - \alpha)$ , firms' pricing strategy has no mass points.*

*Proof.* Suppose there was a mass point at some  $p$ . By Lemma A5,  $p \geq c$ . If  $p > c$ , firms have a profitable deviation to move the mass they place on  $p$  to list a price arbitrarily-close to, but below,  $p$  where there is no mass point. If  $p = c$ ,  $\pi = c/n$ . But a deviation to  $v$  would yield  $v(1 - \alpha)/n > c/n$ . ■

**Lemma A7.** *If  $c < v(1 - \alpha)$ ,  $\nexists x, y \in S$  such that  $(x, y) \notin S$ .*

*Proof.* Suppose there was such a gap in the support  $(x, y)$ . Then firms profit by moving probability density from a neighborhood of  $x$ , to  $y$ . ■

**Lemma A8.** *If  $c < v(1 - \alpha)$ ,  $\bar{s} = v$  and  $\pi = v(1 - \alpha)/n$ .*

*Proof.* Suppose  $\bar{s} < v$ . Then firms profit by moving probability density in a neighborhood of  $\bar{s}$  to  $v$ . Because  $\bar{s} = v$ ,  $\pi = v(1 - \alpha)/n$ . ■

**Lemma A9.** *If  $c < v(1 - \alpha)$ , firms price via  $G(p; c)$  of (3).*

*Proof.* By Lemmas A6 to A8, firms mix continuously over  $S = [\underline{s}, v]$  such that  $\underline{s} \in [c, v)$ . Therefore, for any  $p \in S$ , expected profit must equal that of Lemma A8:

$$v(1 - \alpha)/n = v(1 - \alpha)/n + [p + (n - 1)(p - c)](1 - G(p; c))^{n-1}\alpha/n \quad (12)$$

which is rearranged to give  $G(p; c)$  which is a well defined CDF with  $\underline{s} = [v(1 - \alpha) + c\alpha(n - 1)]/[1 + \alpha(n - 1)]$ . ■

**Lemma A10.** *If  $c \in (v(1 - \alpha), v]$ , PCW profit is zero.*

*Proof.* Suppose PCW profit is positive. Then firms price via mixed strategies: there is some  $p \in S$  such that  $p < \bar{s}$ . One can then follow the proofs of Lemmas A4 to A9. However:

$$\underline{s} = [v(1 - \alpha) + c\alpha(n - 1)]/[1 + \alpha(n - 1)] < c \iff c > v(1 - \alpha), \quad (13)$$

but  $\underline{s} < c$  is a contradiction. Hence firms price via pure strategies, which gives  $\pi = 0$ . ■

**Lemma A11.** *If  $c \in (v(1 - \alpha), v]$ , firms choose some price  $p^* \in [v(1 - \alpha), c]$ .*

*Proof.* By Lemma A10, one price is charged and no sales go through the PCW. Under the proposed equilibrium price firms make  $p^*/n$ . If  $p^* < v(1 - \alpha)$ , a deviation to  $v$  would earn  $v(1 - \alpha)/n > p^*/n$ . If  $p^* > c$ , a firm could profitably undercut the equilibrium price.

It remains to show that any  $p^* \in [v(1 - \alpha), c]$  is an equilibrium price. Take such a price. Any deviation to some  $p < p^*$  reduces profit from a firm's own consumers and, if  $p$  is listed, a loss is made on the active consumers won because  $p < c$ . The best deviation to a higher price is to  $v$ , which yields  $v(1 - \alpha)/n \leq p^*/n$  regardless of whether it is listed. ■

**Lemma A12.** *If  $c = v(1 - \alpha)$ , then firms either price via the mixed strategy of Lemma A9, or the pure strategy  $p^* = v(1 - \alpha)$  of Lemma A11.*

*Proof.* First suppose firms price via a mixed strategy. One can then follow the proofs of Lemmas A4 to A9 which gives  $G(p; v(1 - \alpha))$  of (3), a valid CDF with  $\underline{s} = c$ . Second, suppose firms price via a pure strategy. The price-checks of the proof of Lemma A11 show that the only such equilibrium price is  $p^* = v(1 - \alpha)$ . ■

*Proof of Lemma 1.* Consumers' search and firms' listing is given by Lemma A3. For pricing when  $c < v(1 - \alpha)$ , see Lemma A9; when  $c \in (v(1 - \alpha), v]$ , Lemma A11; and when  $c = v(1 - \alpha)$ , Lemma A12. ■

*Proof of Proposition 2 when  $K = 1$ .* If  $c \geq v(1 - \alpha)$  and firms price via pure strategies, PCW profit is zero, but a deviation to  $c < v(1 - \alpha)$  earns positive profit because firms mix over prices (Lemma 1). Hence  $c \leq v(1 - \alpha)$ . If  $c < v(1 - \alpha)$ , then PCW profit is  $c\alpha(n - 1)/n$  which is linearly increasing in  $c$ , hence a deviation to a slightly higher earns strictly more profit. If  $c = v(1 - \alpha)$  and firms price via mixed strategies, there are no profitable deviations. ■

**A world with multiple PCWs.** This section proves Proposition 2 for multiple PCWs. Let there be  $K > 1$  PCWs indexed  $k = 1, \dots, K$ , where each set a fee level  $c_k$  at  $t = 1$ . I look for symmetric equilibria in which some consumers visit PCWs, which are not found empty PCW on the equilibrium path. Denote  $S$  the support of equilibrium prices,  $\bar{s} = \max\{S\}$ ,  $\underline{s} = \min\{S\}$ , and equilibrium firm profit  $\pi$ . The proof holds for any  $\epsilon > 0$ . I begin by characterizing the equilibrium strategies of firms and active consumers at  $t = 2$  following symmetric commission choices at  $t = 1$  i.e.,  $c_1 = \dots = c_K \equiv c$ .

**Lemma A13.** *If  $c_1 = \dots = c_K \equiv c$ , active consumers visit one PCW; firms list on all PCWs and price as follows where  $G(p; c)$  is defined in (3):*

*if  $c \in [0, v(1 - \alpha))$ , firms price according to  $G(p; c)$ ;*

*If  $c = v(1 - \alpha)$ , either firms price according to  $G(p; c)$ , or firms all charge the price  $p = c$ ;*

*if  $c \in (v(1 - \alpha), v]$ , all firms charge the same price,  $p$ , where  $p \in [v(1 - \alpha), c]$ .*

*Proof.* Note that in order for a PCW not to found empty in equilibrium, firms must list prices on all PCWs. In response, consumers have a strict preference to check exactly one PCW (in the case where  $S$  has one element, see the proof of Lemma A2). In symmetric equilibrium this means each PCW receives  $1/K$  of the active consumers. In turn, this means firms' pricing decision can be treated as if there were only one PCW, the sequence of constructive results used in the single-PCW case (Lemmas A2 to A12) can be followed. The result therefore closely mirrors that with a single PCW (Lemma 1). ■

Next, I characterize the responses of firms and consumers following various unilateral deviations of one PCW (without loss of generality, I let  $k = 1$  be the deviator) from any candidate equilibrium commission choice at  $t = 1$ . In equilibrium, active consumers visit exactly one PCW and PCWs receive  $1/K$  active consumers each (Lemma A13). Consumers do not observe fee levels so their behavior is unaffected by such deviations. Given this, I derive the associated responses of firms. Before proceeding, it is helpful to define the following CDF given a profile of commissions  $\mathbf{c} = (c_1, \dots, c_K)$ :

$$G(p; \mathbf{c}) = 1 - \left[ \frac{(v - p)(1 - \alpha)}{\alpha(np - (n - 1) \sum_k c_k / K)} \right]^{\frac{1}{n-1}} \quad \text{for} \quad p \in [\underline{p}(\mathbf{c}), v], \quad (14)$$

where

$$\underline{p}(\mathbf{c}) = \frac{v(1 - \alpha) + \alpha(n - 1) \sum_k c_k / K}{1 + \alpha(n - 1)}. \quad (15)$$

Note that when  $c_1 = \dots = c_K \equiv c$ ,  $G(p; \mathbf{c})$  becomes  $G(p; c)$  of (3).

**Lemma A14.** *If  $c < v(1 - \alpha)$  in equilibrium, then following a deviation of PCW 1 to  $c_1 \in (c, \underline{p}(c)]$ , firms list on all PCWs and price via  $G(p; c)$ , where  $G(p; c)$  and  $\underline{p}(c)$  are given by (14) and (15). The profit of PCW 1 is  $c_1 \alpha(n - 1)/n$ .*

*Proof.* I find the equilibrium pricing strategy of firms where they list their prices on all PCWs. Close analogs of Lemmas A2 to A9 can be followed. In particular, the analog of Lemma A5 is that  $c_1 \leq \underline{s}$ . The analog of Lemma A9 yields  $G(p; c)$  and  $\underline{p}(c)$  as given by (14) and (15). Note that:

$$c_1 \leq \underline{p}(c) \iff c_1 \leq \frac{v(1 - \alpha) + c\alpha(n - 1)(K - 1)/K}{1 + \alpha(n - 1)(K - 1)/K} \in (c, v(1 - \alpha)), \quad (16)$$

and so that when  $c < v(1 - \alpha)$  it is indeed the case that  $c_1 \leq \underline{s} = \underline{p}(c)$ . Hence, firms strictly prefer to list their prices on all PCWs and  $G(p; c)$  describes their pricing strategy. ■

**Lemma A15.** *If  $c \geq v(1 - \alpha)$  in equilibrium, then following a deviation of PCW 1 to  $c_1 > c$ , the profit of PCW 1 is zero.*

*Proof.* Suppose the profit of PCW 1 is positive. Then firms' pricing strategy must be in mixed strategies. Hence, there is some price  $p < \bar{s}$  listed on PCW 1. The same analogs of Lemmas A2 to A9 followed in Lemma A14 apply, yielding  $G(p; c)$  and  $\underline{p}(c)$  as given by (14) and (15). But  $c_1 > c \geq v(1 - \alpha)$  implies  $\underline{s} = \underline{p}(c_1, c) < c$ , a contradiction. ■

**Lemma A16.** *If  $c \geq v(1 - \alpha)$  in equilibrium, then following a deviation of PCW 1 to  $c_1 \in (0, v(1 - \alpha))$ , the profit of PCW 1 is positive.*

*Proof.* Suppose PCW 1's profit was zero. Then either: (i) firms only ever choose one price,  $p^*$ ; or (ii) firms mix over prices but no firm lists any price below  $\bar{s}$  on PCW 1. (i) If  $p^* > c_1$ , then firms profit by undercutting others (and listing on all sites if  $p^* > c$ ; only PCW 1 if  $p^* \leq c$ ). If  $p^* < c_1$ , then firms profit by deviating to  $v$ . (ii) Any  $p \in S$  such that  $p < \bar{s}$  has a positive probability of being the lowest. It must be that all such  $p \leq c_1$  (firms would list any  $p > c_1$  on PCW 1). Because  $p \leq c_1 < c$ , firms do not list their prices on any PCW. Active consumers do not check firm websites, therefore firms only sell to their own consumers and so there can only be one such  $p$ , giving  $\pi = p/n$ . However, charging  $v$  yields at least  $v(1 - \alpha)/n > p/n$ . ■

*Proof of Proposition 2 when  $K > 1$ .* Suppose  $c < v(1 - \alpha)$  so that firms' pricing is described by the first case of Lemma A13. In equilibrium, each PCW makes  $c\alpha(n - 1)/(nK)$ . By Lemma A14, each PCW has a unilateral profitable deviation upwards to some  $c_k \in (c, \underline{p}(c_k, c))$  yielding profit  $c_k\alpha(n - 1)/(nK)$  (such a deviation raises commission with no reduction in sales). So there is no equilibrium with  $c < v(1 - \alpha)$ .

Suppose  $c \in (v(1 - \alpha), v]$  so that firms' pricing is described by the third case of Lemma A13. By Lemma A15 there is no unilateral profitable deviation upwards for PCWs. However, by Lemma A16 there is a profitable deviation downwards to any fee level in  $(0, v(1 - \alpha))$ . So there is no equilibrium with  $c \in (v(1 - \alpha), v]$ .

Suppose  $c = v(1 - \alpha)$  so that firms' pricing is described by the second case of Lemma A13. By Lemma A15 there is no unilateral profitable deviation upwards for PCWs. If firms charge only one price, then Lemma A16 shows there is a profitable deviation downwards. However, if firms mix over prices then there is no profitable unilateral deviation downwards in commission (such a reduction lowers commission but the quantity of sales is unchanged). Therefore, the unique equilibrium has  $c = v(1 - \alpha)$  set by PCWs at  $t = 1$ , with firms and consumers behaving at  $t = 2$  as described by the second case of Lemma A13 where firms employ mixed-strategy pricing. ■

**Comparative statics.** Here I prove Proposition 3 and Corollary 2.

*Proof of Proposition 3.* First I show that auto-renewers are worse off under the distribution of prices in Proposition 2,  $G^* \equiv G(\cdot; v(1 - \alpha))$ , than that of Proposition 1,  $F_q$ . Auto-renewers pay the price quoted by their current firm and so are worse off if the expected price is higher under  $G^*$ , denoted  $\mathbb{E}_{G^*} > \mathbb{E}_{F_q}$ . I show that this follows because  $G^*$  first-order stochastically dominates (FOSDs)  $F_q$ . The distributions share the same upper bound on their supports, with  $F_q$  having a lower lower bound. Hence,  $G^*$  FOSDs  $F_q$  if  $G^* \leq F_q$  over the support of  $G^*$ ,  $p \in [v(1 - \alpha), v]$ .  $G^* \leq F_q$  can be re-arranged as

$$\left[ \frac{(v - p)(1 - \alpha)}{\alpha q p} \right]^{\frac{1}{q-1}} \leq \left[ \frac{(v - p)(1 - \alpha)}{\alpha n p - \alpha v(1 - \alpha)(n - 1)} \right]^{\frac{1}{n-1}}. \quad (17)$$

To see that this holds, I first note that when  $n = q$  this simplifies to  $\alpha v(1 - \alpha)(n - 1) \geq 0$ , which is always true. Secondly, I show that  $G$  is FOSD-ordered in  $n$ :

$$\frac{dG}{dn} \leq 0 \iff \log \left( \frac{(v - p)(1 - \alpha)}{\alpha(n p - v(1 - \alpha)(n - 1))} \right) + \frac{(n - 1)(p - v(1 - \alpha))}{n p - v(1 - \alpha)(n - 1)} \equiv X(p) \leq 0. \quad (18)$$

Note that  $X(v(1 - \alpha)) = 0$ , and

$$\frac{dX(p)}{dp} \leq 0 \iff p \geq v(1 - \alpha) \left[ \frac{(2n - 2 + \alpha(n - 1)^2)}{(2n - 1 + \alpha(n - 1)^2)} \right]. \quad (19)$$

The term on RHS in square brackets is below 1. Recall that  $p \geq v(1 - \alpha)$  as this is the lower bound of the support, hence  $\frac{dX}{dp} < 0$ .

To show active consumers are worse off under  $G^*$  than  $F_q$ , I first show that  $\mathbb{E}_{F_2}[2]$  (the expected lowest of two draws from  $F_2$ ) is lower than the lower bound of the support of  $G^*$ .

$$\mathbb{E}_{F_2}[2] = \int_{v[\frac{1-\alpha}{1+\alpha}]}^v y(p) p \, dp \quad (20)$$

where  $y(p) = 2(1 - F_2(p)) f_2(p)$  is the density function of the lower of the two draws active

consumers receive from  $F_2$ . Computing yields

$$\mathbb{E}_{F_2}[2] = \left(\frac{1-\alpha}{\alpha}\right)^2 \frac{v}{2} \left[ \log\left(\frac{1-\alpha}{1+\alpha}\right) + \frac{2\alpha}{1-\alpha} \right]. \quad (21)$$

Then  $\mathbb{E}_{F_2}[2] < v(1-\alpha) \iff \log[(1+\alpha)/(1-\alpha)] > 2\alpha$ , which holds for  $\alpha \in (0, 1)$ .

In the case of  $q = 2$ , it is immediate that active consumers are worse off under  $G^*$ . For  $q > 2$ , active consumers face an even lower expected price:  $\mathbb{E}_{F_q}[q] < \mathbb{E}_{F_2}[2]$  (which follows from Proposition 3 of Morgan, Orzen, and Sefton (2006), which applied to my setting says that  $\mathbb{E}_{F_q}[q]$  decreases in  $q$ ). Therefore, relative to  $q = 2$ , the increased benefit from searching  $q - 2$  firm websites when  $q > 2$  is  $\mathbb{E}_{F_2}[2] - \mathbb{E}_{F_q}[q]$ , which by (5) is less than the search cost. ■

*Proof of Corollary 2.* Industry profit of firms is given by  $\alpha\mathbb{E}_{G^*}[n] + (1-\alpha)\mathbb{E}_{G^*} = v(1-\alpha)$ , where  $\mathbb{E}_{G^*}[n]$  denotes the lowest price of  $n$  draws and  $\mathbb{E}_{G^*}[p]$  denotes the expected price from  $G(\cdot; v(1-\alpha))$ . The RHS is the industry profit of firms if it charged  $v$  and only sold to auto-renewers. Differentiating and rearranging,  $d\mathbb{E}_{G^*}[n]/dn = -((1-\alpha)/\alpha)d\mathbb{E}_{G^*}/dn$  so the derivatives have opposite signs. Finally,  $d\mathbb{E}_{G^*}/dn \geq 0$  because  $G(p, v(1-\alpha))$  is stochastically ordered in  $n$  (shown in the proof of Proposition 3). ■

## Appendix B

In this appendix I show that my main results also emerge under “firm-led” price discrimination, ad valorem PCW fees, the presence of meta-sites, and when there is search at the extensive margin, as summarized in the section Comparative Statics.

**Firm-led price discrimination.** I have so far considered a setting in which each firm sets one price such that PCWs provide a pure information aggregation service for consumers. In some markets however, the prices faced by consumers differ across firm websites and PCWs. One way this can manifest is by firms setting different prices on PCWs than they do for direct purchases. I refer to this as “firm-led price discrimination” to distinguish it from the PCW-led discrimination studied in the section Stimulating Inter-PCW Competition.

I let firms set  $K + 1$  prices at  $t = 2$ :  $p_0$  for a direct sale on their own website and  $p_k$  on each PCW  $k = 1, \dots, K$ . I now consider the incentives of firms at  $t = 2$  following a symmetric commission level,  $c$ , at  $t = 1$ . Suppose active consumers visit one PCW where they see all prices. Firms compete fiercely for active consumers in their PCW price down to the commission level (the effective marginal cost), i.e., under symmetry  $p = c$  and firms make no profit from PCW sales. Firms then face a trade-off in their direct price. They either set the highest direct price such that they sell to their own consumers directly,  $c$ , or the highest direct price such

that they sell to only their auto-renewers,  $v$ .<sup>28</sup> The former makes a firm  $c/n$ , while the latter makes  $v(1 - \alpha)/n$ . Therefore, when  $c \leq v(1 - \alpha)$  firms prefer to discriminate, exploiting auto-renewers through a high direct price. When  $c \geq v(1 - \alpha)$  firms prefer not to discriminate but rather to prompt all their consumers to buy directly, albeit at a lower price.

Now consider PCWs' choice at  $t = 1$ . PCWs strongly prefer that firms discriminate, just as they want firms to set dispersed prices in the setting with uniform pricing. Where there is no discrimination,  $c$  is the only price available and the market for switching shuts down: all consumers buy directly and PCWs make zero profit. When firms set a higher price on their own websites than on the PCW, all active consumers purchase through PCWs. PCWs therefore set the highest fee possible such that firms are willing to price discriminate, and  $c = v(1 - \alpha)$  results.

In such an equilibrium firms make  $v(1 - \alpha)/n$  and have no profitable deviations: they extract the full surplus from auto-renewers; winning any active consumers through PCWs can only be done at a loss (charging less than  $c$ ); selling to their own active consumers directly involves undercutting the PCWs with the price on their own website (generating profit no more than  $c/n = v(1 - \alpha)/n$ ). Checks that  $c = v(1 - \alpha)$  is part of an equilibrium are similar to those in the analysis without discrimination. There is no profitable unilateral deviation down to a lower commission level because such deviations serve only to reduce revenue. Following a unilateral deviation up, there are mutual best responses of firms to the uniform price  $p_0 = p_1 = \dots = p_K = v(1 - \alpha)$  that shut down the market for switching.

In the world without PCWs, the expected price paid by active consumers was strictly less than the lower bound of prices in the world with a PCW,  $v(1 - \alpha)$ . In the setting with price discrimination,  $v(1 - \alpha)$  is the price paid by active consumers, and so they are still worse off with PCWs. Auto-renewers now pay the monopoly price; price discrimination has hurt them because now they do not benefit from the “search externality” (see Armstrong, 2015) generated by active consumers in the case where firms set one price. Proposition B1 summarizes.

**Proposition B1 (Firm-led price discrimination).** *There exists an equilibrium in which  $K \geq 1$  PCWs set a fee of  $c = v(1 - \alpha)$ , firms set a price of  $p_0 = v$  on their own websites and list  $p_k = v(1 - \alpha)$  on each PCW. Active consumers visit exactly one PCW. Both types of consumer are worse off with PCWs than without.*

The equilibrium of Proposition B1 is essentially equivalent to that reported under PCW-led price discrimination (Proposition C2): it is payoff-equivalent and the effective prices paid by both types of consumers are the same so that both types of consumers are worse off relative to the world without the PCW. In both settings, consumers pay  $v(1 - \alpha)$  for a purchase through the PCW, a price determined by firms' outside option. With firm-led discrimination, the PCW

<sup>28</sup>If  $c = v$ , there is no trade-off for firms and all prices are  $v$ .



controls the price charged on it via its choice of commission and sets it as high as possible before firms free-ride, which shuts down the market for switching. With discounts, the PCW charges the monopoly commission to firms while controlling the effective price charged on it via its choice of discount, setting the discount as low as possible before firms prefer to sell to their own consumers by de-listing from, and undercutting the PCW.

**Ad valorem commission.** In some markets, PCWs charge firms a percentage of the purchase price for each sale, rather than a fixed per-unit amount. Here I show that under such fees, the price-raising result of Proposition 3 continues and that price dispersion is maintained in equilibrium.

Consider a single PCW. In equilibrium, the PCW is able to extract the full price charged by a firm for a sale made through it. As such, the distribution of prices is distinct from that with a constant per-sale fee ( $G(\cdot; c)$ ), but has the same support, hence active consumers are worse off with the PCW. However, it also first-order stochastically dominates the distribution of prices in the world without a PCW ( $F_q$ ), hence auto-renewers are also worse off. The equilibrium is detailed in Proposition B2 below.

With multiple PCWs the analogous equilibrium exists in which each PCW extracts the full price and prices are distributed identically to the monopoly case. As in the case of per-unit commission, firms list ubiquitously and active consumers visit one PCW, leaving PCWs with no incentive to reduce their fee.

Although PCWs extract the full sale price from firms given ad valorem fees, price dispersion emerges in equilibrium. This is because the PCW cannot extract all the surplus that firms make from active consumers. Specifically, firms' own active consumers renew directly, which represents sales that PCWs cannot monetize. Indeed, in equilibrium with ad valorem fees, when a firm is cheapest, say at some price  $p$ , it makes nothing on rival firms' active consumers because the full price is extracted by the PCW, but it makes  $p$  on its own active consumers. Therefore, firms still have some positive surplus to compete for on the PCW, which produces price dispersion in equilibrium.

**Proposition B2.** *Suppose a single PCW charges a proportion of the sale price,  $\lambda \in [0, 1]$ , to firms instead of a fixed commission. In the unique equilibrium, the PCW sets a fee equal to the sale price i.e.,  $\lambda = 1$ , firms list on the PCW and mix over prices according to:*

$$L(p) = 1 - \left[ \frac{(v-p)(1-\alpha)}{p\alpha} \right]^{\frac{1}{n-1}} \text{ over the support } p \in [v(1-\alpha), v].$$

*Proof.* Many parts of the proof are similar to those with fixed per-sale fees so those details are omitted. Firstly, notice that in any equilibrium,  $\lambda = 1$ . This is because for any  $\lambda \in [0, 1)$  all firms list their prices and mix over an interval of prices with no point masses. Because firms

list ubiquitously, active consumers check only the PCW. Furthermore, these distributions are first-order stochastically ordered in  $\lambda$  where a higher  $\lambda$  corresponds to higher prices. Therefore, the PCW would prefer to raise  $\lambda$ . The only remaining candidate is  $\lambda = 1$ . When a firm sells, it is the cheapest, it sells to other firms' consumers through the PCW, and all the rent is extracted by the PCW because  $\lambda = 1$ . However, when it is cheapest it also sells to its own consumers, for whom the sale is completed directly. In equilibrium, the firms therefore only compete for their own active consumers. This results in the familiar equilibrium indifference relation for a firm between charging  $v$  and only selling to its auto-renewers, or charging another price  $p < v$  in the equilibrium support which generates sales to auto-renewers and when it is the lowest price charges, also to active consumers:  $v(1 - \alpha)/n = p(1 - \alpha)/n + p(1 - L(p))^{n-1}\alpha/n$  which rearranges to give  $L(p)$ , a well-defined CDF over the support  $p \in [v(1 - \alpha), v]$ . ■

**Meta-sites.** In recent years, “meta-sites” have entered the marketplace. These sites typically list all prices including those listed on PCWs.<sup>29</sup> However, with active consumers incentivized to check only the meta-site, the logic of my primary analysis regarding an aggregator of firms' prices applies to this aggregator of firms and aggregators: in equilibrium, the meta-site extracts all the surplus from PCWs, that in turn pass it on to firms, that in turn pass it on to consumers in higher prices. Proposition B3 details the equilibrium.

Specifically, the introduction of the meta-site is equivalent to consumers attending all PCWs i.e., consumers see prices from all PCWs simultaneously. This leads to Bertrand competition at the aggregator level, and PCWs make zero profits. However, the meta-site is able to charge the monopoly fee of  $v(1 - \alpha)$  to PCWs, who pass it on to firms, who pass it on to consumers, who again all end up worse off than with no aggregators or meta-sites. One can then see how this logic would extend to “meta-meta-sites” and beyond.

**Proposition B3.** *Suppose there are  $K \geq 1$  PCWs and a meta-site which charges a commission at  $t = 1$ . There is an equilibrium in which the meta-site sets a commission of  $v(1 - \alpha)$ , the PCWs set  $c = v(1 - \alpha)$ , firms list either on the PCW or the meta-site, or both, and mix over prices according to  $G(p; v(1 - \alpha))$  over the support  $p \in [v(1 - \alpha), v]$ .*

*Proof.* All prices are available via the meta-site, so active consumers are happy to visit only the meta-site. The meta-site (or any PCW) has no incentive to raise its fee: If it did, then, similarly to Lemma 1, pure pricing on the meta-site (or PCW) would ensue and no consumers switch. Firms face the same incentives as in Proposition 2 because no matter which channel they sell to active consumers through, they incur a per-unit cost of  $v(1 - \alpha)$ : If they sell through a direct listing on the meta-site, they pay the fee to the meta-site; if they sell through a PCW listed on the meta-site, they pay the fee to the PCW. Therefore, i) firms have no incentive to de-list from any PCW or meta-site; and ii) the pricing strategy is the same as in Proposition 2. ■

<sup>29</sup>Examples of such meta-sites include [www.kayak.com](http://www.kayak.com) and [www.trivago.com](http://www.trivago.com).

**The extensive search margin.** The auto-renewers in my model are inactive and can be interpreted as being offline, loyal, uninformed, or just as having high search costs. Here, I focus on a search-cost rationalization that can describe markets such as home insurance where obtaining a quote requires more information, and hence time or effort, from the consumer. In an environment without a PCW where auto-renewers find it too costly to enter these details into a firm’s website to retrieve one extra price, the introduction of PCWs offers to expose all prices to them, for the same single cost. Depending on their search cost, the introduction of PCWs may then cause an auto-renewer to engage in comparisons via PCWs. Some empirical studies have offered a similar argument to explain observed increases in market competitiveness (e.g., Brown and Goolsbee, 2002; Byrne, de Roos, and Tiong, 2014). Their arguments are distinct from mine because they contrast a world with web-based aggregators relative to a world without the Internet rather than a world with the Internet and firm websites. This engagement of new customers is commonly referred to as the “extensive search margin” (for a discussion see Moraga-González, Sándor, and Wildenbeest, 2017).

For an inactive consumer the benefit of an additional search in the world without PCWs is the difference between the expected price and the expected lowest of two prices drawn from  $F_q$ . With PCWs, the benefit of a search on a PCW is the difference between the expected price and the expected lowest of  $n$  draws from  $G(\cdot; v(1 - \alpha))$ .<sup>30</sup> I denote these search benefits with and without an aggregator respectively as  $\mathcal{B}_1 = \mathbb{E}_{G^*} - \mathbb{E}_{G^*}[n]$  and  $\mathcal{B}_0 = \mathbb{E}_{F_q} - \mathbb{E}_{F_q}[2]$ , where the notation is the same as in (22). The model is as before save that each auto-renewer faces a search cost  $s$ . I assume these costs are heterogeneous, distributed according to  $S$  over  $s \in [\underline{s}, \infty)$ .<sup>31</sup> I assume that  $\underline{s} > \mathcal{B}_0$  so that without PCWs, no auto-renewers shop, preserving the equilibrium of Proposition 1 in the world without PCWs. After the introduction of PCWs, the benefit of a search,  $\mathcal{B}_1$ , may outweigh the cost,  $s$ , for some auto-renewers, who then choose to use the site. I use the term “converts” and “non-converts” to distinguish between auto-renewers who decide to shop or not in equilibrium with a PCW.

The total number of consumers using PCWs (active consumers and converts) is endogenously determined in equilibrium and is denoted  $\tilde{\alpha} \equiv \alpha + (1 - \alpha)S(\mathcal{B}_1)$ . Given  $\tilde{\alpha}$ , PCWs set  $c = v(1 - \tilde{\alpha})$ . Because  $c$  and  $\tilde{\alpha}$  are exogenous to firms, equilibrium pricing is as in Proposition 2 with  $\tilde{\alpha}$  replacing  $\alpha$ . In turn, this pricing determines  $\mathcal{B}_1$ . There is an equilibrium when this value of  $\tilde{\alpha}$  satisfies  $S(\mathcal{B}_1) = \frac{\tilde{\alpha} - \alpha}{1 - \alpha}$ . When there exists such an  $S$ , I say that  $\tilde{\alpha}$  is “rationalized”.

Corollary 3 showed that a higher  $\alpha$  increases the welfare of all consumers. Corollary 1 showed that a lower  $c$  has the same effect. Because the equilibrium fee level is  $v(1 - \tilde{\alpha})$ , both forces work to benefit all types of consumer. However, whether consumers actually gain depends on how many auto-renewers are converted. If the benefit  $\mathcal{B}_1$  is small or there are no types with

<sup>30</sup>These terms are analogous to the “value of information” in Varian (1980).

<sup>31</sup>That there is no upper bound ensures that there are always some auto-renewers in equilibrium.

low search costs so that  $S(\mathcal{B}_1) = 0$ , there are no converts ( $\tilde{\alpha} = \alpha$ ) and the equilibrium of Proposition 2 applies. For a given PCW search benefit  $\mathcal{B}_1$ , when more auto-renewers have low search costs,  $S(\mathcal{B}_1)$  is higher,  $\tilde{\alpha}$  is higher,  $c$  is lower and total consumer welfare is higher. However, relative to the world without PCWs, the presence of converts fails to guarantee lower prices for any consumer, even for the converts themselves, as Proposition B4 states.

**Proposition B4.** *Active consumers, converts and non-converts can all be worse off with a PCW than without.*

*Proof.* This is a proof by example. Let  $v = 1$ ,  $\alpha = 0.7$ ,  $n = 3$  and  $q = 2$ . Then, in the world without a PCW, it can be computed that

$$\mathbb{E}_{F_2} = 0.3717, \quad \mathbb{E}_{F_2}[2] = 0.2693, \quad \mathcal{B}_0 = 0.1024.$$

In the world with a PCW, assume  $\tilde{\alpha} = 0.71$  (i.e., the PCW attracts 0.01 more consumers i.e., 1/30 auto-renewers, to compare prices), so  $c = v(1 - \alpha) = 0.29$  and

$$\mathbb{E}_{G(\cdot; c)} = 0.5557, \quad \mathbb{E}_{G(\cdot; c)}[3] = 0.3748, \quad \mathcal{B}_1 = 0.1808.$$

Comparing, one can see that if there is an  $S$  such that this can be rationalized as an equilibrium, then all types of consumer will be worse off with a PCW than without. To rationalize, I construct an  $S$  such that:

$$S(\mathcal{B}_1) = \begin{cases} 0 & \text{if } \mathcal{B}_1 < \underline{s} \\ \frac{\mathcal{B}_1 - \underline{s}}{\mathcal{B}_1} & \text{else} \end{cases}$$

where  $\underline{s}$  is determined by  $S(0.1808) = 1/30 \iff \underline{s} = 0.1748 > \mathcal{B}_0$ . ■

## Appendix C

This appendix provides results with a single PCW, referred to in the main text of the section Stimulating Inter-PCW Competition.

**Proposition C1 (Access fees; single PCW).** *With a single PCW, there is a unique equilibrium in which the PCW sets an access fee of*

$$b^* = \mathbb{E}_{G^*}[q] - \mathbb{E}_{G^*}[n] + (q - 2)\epsilon, \quad (22)$$

where  $\mathbb{E}_{G^*}[m]$  denotes the expected lowest of  $m$  draws from the distribution  $G(\cdot; v(1 - \alpha))$ , and strategies are otherwise those of Proposition 2. In this equilibrium, both types of consumer are worse off with a PCW than without.

*Proof.* It remains to determine the equilibrium access fee level,  $b^*$ , which is given by the outside option of consumers: on the PCW, active consumers compare all  $n$  prices; abandoning the PCW they compare  $q$  prices and pay search costs of  $(q - 2)\epsilon$ , hence (22) follows. A lower access

fee would leave consumers with extractable surplus. A higher access fee cannot be part of an equilibrium with PCW use because consumers would rather search  $q$  firm websites than access the whole market through the PCW. ■

**Proposition C2 (PCW-led discrimination; single PCW).** *With a single PCW, there is an equilibrium in which the PCW sets a fee  $c = v$  and a discount  $d = v\alpha$ ; firms list a price  $p = v$  on the PCW such that active consumers pay the effective price  $v(1 - \alpha)$ . Active consumers visit only the PCW. Both types of consumer are worse off with the PCW than without.*

*Proof.* To construct an equilibrium, take the PCW's choice of commission and discount at  $t = 1$ ,  $(c, d)$ , as given; and at  $t = 2$ , suppose firms list and consider their pricing decision. From the perspective of firms, one difference from the analysis without discounts is that all active consumers, including their own, now buy through the PCW when  $d > 0$ . However, firms still face a tension between setting a high price to exploit auto-renewers and a lower price to win rivals' active consumers. As in the case without discounts, this tension leads firms to price via mixed strategies, where the analogous expression to (2) is:

$$(v - p)(1 - \alpha) = \alpha n(p - c)(1 - H(p; c))^{n-1} \Leftrightarrow H(p; c) = 1 - \left[ \frac{(v - p)(1 - \alpha)}{\alpha n(p - c)} \right]^{\frac{1}{n-1}}, \quad (23)$$

which is a well defined CDF over  $[\underline{p}', v]$ , where  $\underline{p}' = (v(1 - \alpha) + \alpha nc)/(1 + \alpha(n - 1))$ . In equilibrium, firms must not find it profitable to de-list and charge some  $p - d$  where  $p \in [\underline{p}', v]$ ; a deviation that loses the firm all revenue from PCW sales, but sells to their own consumers without incurring commission. Profit from this deviation is

$$(p - d) \left[ (1 - \alpha)/n + (1 - H(p; c))^{n-1} \alpha/n \right], \quad (24)$$

which is convex in  $p$ , so the optimal deviation is to  $\underline{p}' - d$ , giving a profit of  $(\underline{p}' - d)/n$ . It follows that firms pricing via (23) is part of an equilibrium if

$$v(1 - \alpha)/n \geq (\underline{p}' - d)/n \iff d \geq \frac{c\alpha n - v(1 - \alpha)\alpha(n - 1)}{1 + \alpha(n - 1)} \equiv \underline{d}(c). \quad (25)$$

In words, when the PCW offers a large enough discount relative to commission, firms are unwilling to de-list from the PCW to charge a price that undercuts all the discounted PCW prices. Turning to the PCW's choices at  $t = 1$ , it sets  $(c, d)$  such that  $d \geq \underline{d}(c)$ , making a profit of  $\alpha(c - d)$ .<sup>32</sup> Because PCW profits are increasing in  $c$  and decreasing in  $d$ ,  $d = \underline{d}(c)$ . From (25),  $\partial \underline{d}(c)/\partial c < 1$ , which implies that the optimal PCW choices are  $c = v$  and  $d = \underline{d}(v) = v\alpha$ . Firms respond by listing a price distributed by  $H(p; v)$ , which is a degenerate distribution on the monopoly price  $v$ . Proposition C2 summarizes.

<sup>32</sup>Note that when the PCW chooses  $(c, d)$  such that  $d < \underline{d}(c)$ , the only equilibrium in which the PCW is not found empty by consumers on the equilibrium path is where firms and consumers shun the PCW, meaning that the equilibrium strategies of the world without a PCW apply (Proposition 1) and the PCW makes zero profit.

In equilibrium, consumers effectively pay  $v(1 - \alpha)$  (the price less the discount) for a purchase through the PCW, a value determined by firms' outside option. The PCW charges the highest possible commission while controlling the effective price charged on it via its choice of discount, setting the discount as low as possible (the effective price as high as possible) such that firms prefer not to sell to their own consumers by de-listing from and undercutting the PCW. The effective commission (the commission less the discount) is the same as that charged in the setting without discounts (Proposition 2). That is, the PCW's commission completely compensates it for the discounts it uses in order to ensure it sells to all active consumers. ■

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